GENERAL GUIDELINES
FOR THE
HYDROLOGIC-HYDRAULIC ASSESSMENT
OF
FLOODPLAINS IN INDIANA

Comments or questions regarding these guidelines are always welcome. The Department of Natural Resources intends to update this document on a regular basis as changes and improvements warrant. You can contact the Division of Water by the following means:

- E-Mail your questions or comments to:
  water_inquiry@dnr.state.in.us
- Send questions or comments to:
  Indiana Department of Natural Resources
  Division of Water
  402 West Washington Street, Room W264
  Indianapolis, IN 46204
- Call or fax your questions or comments to these Division of Water numbers:
  Main office - (317) 232-4160 or toll free 1-877-928-3755
  Fax number - (317) 233-4579

In order to help us track and compile comments regarding these guidelines, e-mail is the preferred option for your general comments. If using the e-mail portion of our website, enter “guideline comment” in the field labeled “Staff Name”.

Indiana Department of Natural Resources
Division of Water
Indianapolis, Indiana
December 5, 2002

PREFACE

General Guidelines for the Hydrologic-Hydraulic Assessment of Floodplains in Indiana was created to assist the floodplain management community in establishing base flood elevations and floodway limits and in evaluating projects in accordance with the Indiana Flood Control Act and the National Flood Insurance Program. The guidelines detail methods acceptable to both the Indiana Department of Natural Resources (IDNR) and the Federal Emergency Management Agency (FEMA) with respect to hydrologic and hydraulic modeling and floodplain mapping. Also included in this guide are recommendations on presenting results of a floodplain study and other useful reference material.

As noted above, these guidelines are intended to assist the floodplain management community. They are geared to a knowledgeable audience and are not meant to be a self contained document.

This guide was authored by a team of water resource professionals representing the IDNR - Division of Water and engineering consulting firms active in the area of water resources in the state of Indiana. The team members are:

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CONTENTS

LIST OF ABBREVIATIONS

BFE	Base Flood Elevation
CAD	Computer Aided Drafting
CFR	Code of Federal Regulations
CLOMR	Conditional Letter of Map Revision
CR	Contraction Ratio
DEM	Digital Elevation Model
DOQ	Digital Orthophoto Quadrangle
DOW	Division of Water (within IDNR)
ER	Expansion Ratio
ESC	Engineering Services Center (part of Division of Water)
FARA	Floodplain Analysis Regulatory Assessment
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study (used by FEMA)
FW	Floodway
GIS	Geographic Information System
HD	Hydraulic Depth (average)
HEC	Hydrologic Engineering Center
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center – River Analysis System
IAC	Indiana Administrative Code

IC	Indiana Code
ICPR	Interconnected Pond Routing Model
IDNR	Indiana Department of Natural Resources
INDOT	Indiana Department of Transportation
L	Reach Length
LOMA	Letter of Map Amendment
LOMR	Letter of Map Revision
LOMR-F	Letter of Map Revision – Based on Fill
LPA	Local Public Agency
n	Roughness Coefficient Used in the Manning Equation
NAVD-1988	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NGVD-1929	National Geodetic Vertical Datum of 1929
NRC	Natural Resources Commission
NRCS	Natural Resources Conservation Service
PMR	Physical Map Revision
S	Average Reach Slope in Percent
TIN	Triangulated Integrated Network
TR-20	Technical Release 20 (used by NRCS)
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WSP2	Water Surface Profiles 2 (used by NRCS)
WSPRO	Water Surface Profiles (used by FHWA)

LINKS

Indiana Flood Control Act: http://www.in.gov/legislative/ic/code/title14/ar28/ch1.html

Indiana Floodplain Management Act:

http://www.in.gov/legislative/ic/code/title14/ar28/ch3.html

312 IAC 10 Floodplain Management Rule: http://www.in.gov/legislative/iac/title312.html

Request for Floodplain Information: http://www.in.gov/icpr/webfile/formsdiv/50356.pdf

44 CFR

http://www.access.gpo.gov/nara/cfr/waisidx_99/44cfr59_99.html

http://www.access.gpo.gov/nara/cfr/waisidx_99/44cfr60_99.html

http://www.access.gpo.gov/nara/cfr/waisidx_99/44cfr65_99.html

http://www.access.gpo.gov/nara/cfr/waisidx_99/44cfr67_99.html

http://www.access.gpo.gov/nara/cfr/waisidx_99/44cfr70_99.html

FEMA Guidelines (Feb 2002)

http://www.fema.gov/mit/tsd/dl_cgs.htm

MT-2 Forms

http://www.fema.gov/mit/tsd/dl_mt-2.htm

Division of Water links

Floodplain Mapping:

http://www.in.gov/dnr/water/publications/index.html

County / City Mapping: <under construction>

FEMA workmaps: <under construction>

Benchmarks: http://www.in.gov/dnr/water/comm_assistance/benchmarks/index.html

H & H Modeling: http://www.in.gov/dnr/water/surface_water/hydro_hydraulic/index.html

Coordinated Discharges:

http://www.in.gov/dnr/water/surface_water/coordinated_discharges/index.html

Rainfall Frequency:

http://www.in.gov/dnr/water/surface_water/rainfallfrequency/index.html

Drainage Areas of Indiana Streams:

http://www.in.gov/dnr/water/surface_water/drainage_area/index.html

Modeling Checklist:

http://www.in.gov/dnr/water/surface_water/pdf/fp_guidelines_checklist.pdf

USGS Mapping links

DOQ: http://www-wmc.wr.usgs.gov/doq/

Quads: http://mcmcweb.er.usgs.gov/topomaps/

30 Meter DEM: http://mcmcweb.er.usgs.gov/status/dem_stat.html

Drainage Areas of Indiana Streams: http://in.water.usgs.gov/cdfactsheet/arcinfo.html

HEC-RAS: http://www.hec.usace.army.mil/

CheckRAS: http://www.fema.gov/mit/tsd/frm_crdl.htm

WSPRO: http://water.usgs.gov/software/wspro.html

E431: http://water.usgs.gov/software/e431.html

ICPR: http://www.streamnologies.com/icpr.htm

WRAS: http://www.wcc.nrcs.usda.gov/water/quality/common/hec-ras/hecraspg.html

EXECUTIVE SUMMARY

General Guidelines for the Hydrologic-Hydraulic Assessment of Floodplains in Indiana was created to assist the floodplain management community in establishing base flood elevations (BFEs) and floodway limits and in evaluating projects in accordance with the Indiana Flood Control Act and the National Flood Insurance Program. Members of the floodplain community and, therefore, the intended audience of these guidelines includes individual property owners, developers, engineers, surveyors, elected and appointed officials and interested citizens.

The guidelines were authored by a team of water resource professionals representing the Indiana Department of Natural Resources (IDNR) – Division of Water and engineering consulting firms active in the area of water resources in the state of Indiana. The current version of these guidelines is available at the IDNR website (http://www.in.gov/dnr/ water).

Chapter 1 reviews federal and state floodplain acts and codes, defines some key terms and expands on the purpose of the guidelines. The process of obtaining BFEs and floodway limits for projects consisting of a single lot and/or structure is explained in Chapter 2. In these cases, the IDNR may provide or calculate the BFE.

Chapter 3 provides an overview of detailed floodplain analyses. Historically, the IDNR has provided BFEs and floodway limits for proposed developments in unstudied areas, assuming the area of contributing watershed at the development is greater than one square mile. As of July 1, 2002, the Department required that these hydrologic-hydraulic assessments be performed by the requester and submitted to the IDNR for review and approval. Overview topics discussed in Chapter 3 include gathering data and information, submitting analyses to IDNR, revising existing BFEs and/or floodway limits, and computer model requirements. Subsequent chapters elaborate on the overview topics.

Suggestions for selecting or creating a map suitable for plotting floodplain and floodway limits are offered in Chapter 4. Chapter 5 prescribes surveying standards and suggests surveying methods likely to lead to determination of BFEs and plotting of floodplain and floodway limits acceptable to the IDNR.

Computer modeling is discussed in Chapter 6. This chapter provides guidance on potential model sources and offers suggestions on how to evaluate the suitability of a model. The overall thrust of this chapter is to facilitate optimum use of existing modeling. Chapter 7 temporarily shifts the guideline’s emphasis from hydraulics, to hydrology, that is, from BFE’s and floodplain and floodway limits to flood flows. Described are three options for determining peak discharges acceptable to IDNR.

Returning to hydraulics, Chapter 8 offers suggestions for more effectively creating and using a HEC-RAS model. HEC-RAS, a widely used hydraulic model developed by the U.S. Army Corps of Engineers, is preferred by the IDNR for floodplain analyses. Chapter 9 recognizes that other hydraulic models may occasionally be used. Accordingly, this chapter discusses issues that should be considered when using such models. Finally, Chapter 10 provides suggestions on how to effectively present to the IDNR the modeling that supports a floodplain hydrologic-hydraulic assessment. Included is a discussion of a modeling checklist.

General Guidelines for the Hydrologic-Hydraulic Assessment of Floodplains in Indiana, is a living document whose content will be continuously refined in response to improvements in the art and science of floodplain analyses as the IDNR interacts with the floodplain community. In the spirit of continuous improvement, the IDNR welcomes questions and suggestions. Refer to the title page for contact information.

Keywords: base flood elevation, cumulative effects, Federal Emergency Management Agency (FEMA), flood hazard, floodplain, floodway, hydraulics, hydrology, Indiana Department of Natural Resources (IDNR), modeling, regulation

CHAPTER 1

INTRODUCTION

1.1 Historic Overview

Congress created the National Flood Insurance Program (NFIP) in 1968 to alleviate some problems associated with flooding along rivers, streams and lakes. Local communities participate in the NFIP by adopting and enforcing ordinances incorporating all applicable state and federal floodplain regulations. Participation in the program enables residents of the community to purchase flood insurance. The NFIP was expanded by the passage of the Flood Disaster Protection Act (1973) and the National Flood Insurance Reform Act (1994).

As part of the NFIP, the Governor of each state assigns a state agency or office to act as the coordinating agency for the NFIP. This agency serves as the administrator of the NFIP, working with local, state and federal entities in assisting local communities in enforcing floodplain management standards. Indiana's NFIP coordinating agency is the Department of Natural Resources (IDNR), Division of Water (DOW).

The Indiana General Assembly passed the Indiana Flood Control Act (Indiana Code 14-28-1) in 1945, recognizing that preventing and limiting damaging effects of floods was in the best interest of Indiana's citizens. The Indiana Flood Control Act, Indiana Code (IC) 14-28-1, is available at the IDNR website (http://www.in.gov/dnr/water). According to the Act, constructing a permanent abode or placing a residence in a floodway is prohibited. Any other structure, obstruction, deposit, or excavation in the floodway of any stream in the state must first be approved by the Natural Resources Commission (NRC). The Commission granted authority to the IDNR's Division of Water to act on its behalf concerning the state's flood control activities.

Proposed construction activities in a floodway are reviewed by the Department to determine if the work will:

- Adversely affect the efficiency or unduly restrict the capacity of the floodway
- Create an unreasonable hazard to life or property
- Result in unreasonably detrimental effects upon fish, wildlife and botanical resources

In 1973, the Indiana General Assembly directed the NRC to establish minimum standards for the delineation and regulation of all flood hazard areas in the state by passing the Indiana Floodplain Management Act (IC 14-28-3). The Act is available at the IDNR website (http://www.in.gov/dnr/water). The Commission responded by promulgating the Flood Hazard Area Rules, known presently as the Floodplain Management Rules. The latest version of these rules now resides under 312 Indiana Administrative Code 10 (312 IAC 10) and is available on the IDNR website (http://www.in.gov/dnr/water). These are minimum standards to be used by local units of government in developing floodplain management ordinances to regulate the flood hazard areas within their jurisdiction.

1.2 Terminology

Computer models are created by representing the physical characteristics of the watershed and floodplains and using historical flood information. Key terms that often occur in modeling discussions are described below and some are illustrated in Figure 1-1.

Hydrology: multidisciplinary subject addressing the occurrence, circulation and distribution of waters of the earth. In floodplain management, hydrology refers to the rainfall – runoff portion of the hydrologic cycle as it applies to extreme events. In a floodplain study, hydrology is used to estimate flood flow rates. Common methods are stream gage analysis, rainfall-runoff models, or a combination of the two.

Hydraulics: study of the mechanical behavior of water in physical systems and processes. In floodplain management, hydraulics refers to determination of the lateral and vertical extent of a particular flood. Hydraulics also encompasses the flow characteristics around and through hydraulic structures such as bridges, culverts and weirs.

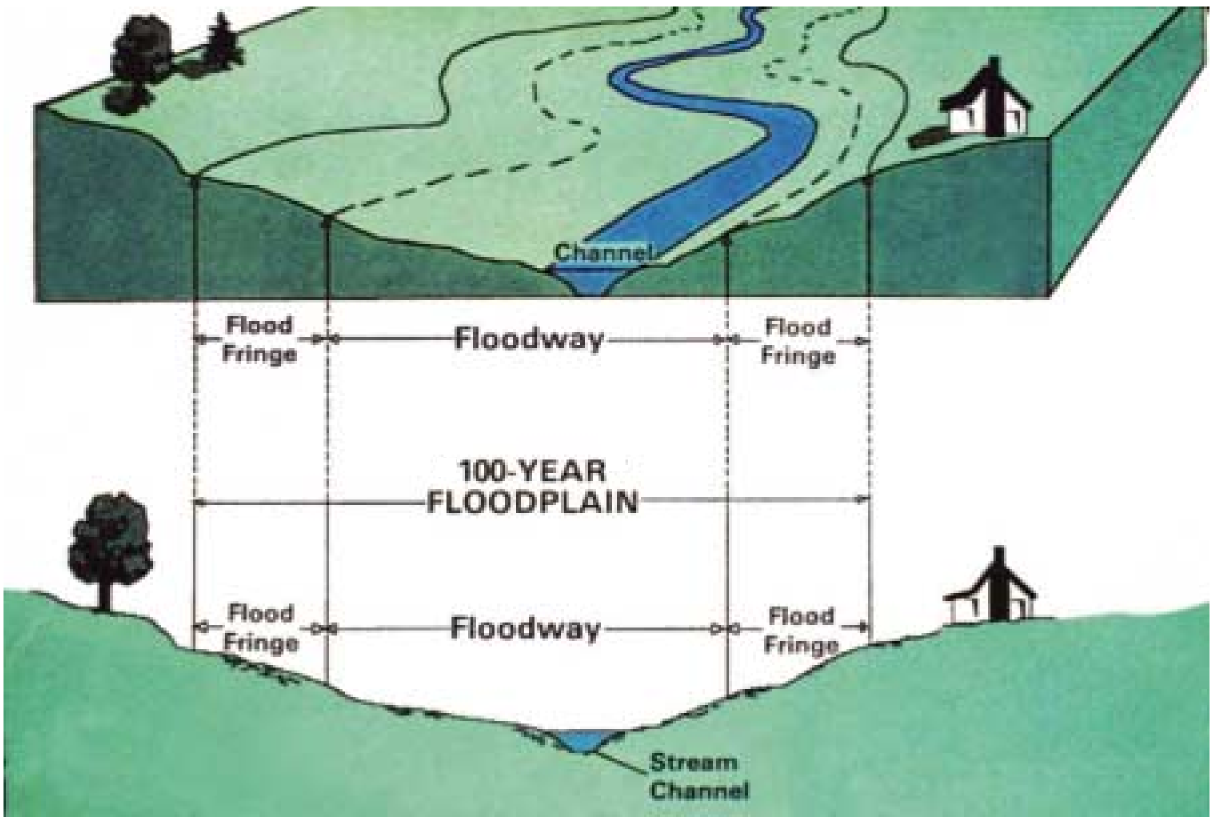
Base flood elevation (BFE): elevation of the flood having a one percent chance of being equaled or exceeded in any given year. This flood is the regulatory standard of both the NFIP and the Indiana Flood Control Act. This flood is also known as the 100-year flood or the regulatory flood.

Floodplain: usually wide, flat to gently sloping area contiguous with and typically lying on both sides of a channel. For regulatory purposes, the floodplain corresponds to the lateral extent of the BFE.

Floodway: the channel of a river or stream and those portions of the floodplains adjoining the channel which are reasonably required to efficiently carry and discharge the peak flood flow of the regulatory flood of any river or stream. The floodway is the portion of the floodplain where the IDNR has jurisdiction, based on the Indiana Flood Control Act. Floodway delineation based on Indiana standards is more stringent than floodway delineation following federal criteria.

Flood fringe: portions of a regulatory floodplain lying outside of the floodway.

Figure 1-1. The floodplain consists of the floodway and flood fringe.



1.3 Purpose of Guidelines

The objective of these guidelines is to assist the engineering community in the State of Indiana to successfully complete floodplain analyses, whether for the evaluation of a project for construction purposes, or for the initial identification of the flooding potential of a stream. The guidelines are also intended as a resource for answering common questions that arise in the process of completing a floodplain model. Finally, these guidelines were created with the purpose of increasing the quality of the modeling submitted to the IDNR for review, and to assist the IDNR in the timely review of these models.

This document is intended to replace the previous IDNR document “Suggested Division of Water Procedures for Hydraulic Modeling,” dated October 26, 1994. Other agencies have procedures that they must follow, but where they are not mutually exclusive, these guidelines should be followed. The committee formed to draft this document tried to rectify some of the inconsistencies that have been noted between IDNR practices and the practices of other agencies.

The profession of floodplain management and the sciences of hydrology and hydraulics are evolving, as advances are made. Therefore, this document should be considered a “living” document in that it will probably be frequently updated. To obtain the latest version of these guidelines, please check the IDNR website (http://www.in.gov/dnr/water).

These guidelines are not meant to exclude other approaches that apply more directly to a given situation. The IDNR provides no assurance that adherence to these guidelines will result in an acceptable model**.** Modeling and other floodplain analyses should be directed by a licensed engineer experienced in hydrology and hydraulics.

CHAPTER 2

OBTAINING A FLOODPLAIN DETERMINATION FOR A MINOR SITE ASSESSMENT

2.1 Purpose

This chapter explains the process of obtaining Base Flood Elevations (BFEs) and floodway limits for projects consisting of a single residential lot and/or a single residence and/or out building. Typically, these determinations are done to evaluate an application for a Letter of Map Amendment (LOMA) for an existing residence and/or out building, or to provide the BFE for a proposed structure on property near a stream or lake. A LOMA is a letter action by the Federal Emergency Management Agency (FEMA) which revises the currently effective flood map. These assessments may not require the same level of detailed floodplain or floodway analysis typically needed for larger developments.

2.2 Overview

Figure 2-1 presents an overview of the process used to obtain a BFE and/or floodway limits for a single residential lot or residence and/or out building. A requester should begin by submitting the “Request for Floodplain Information” form to the IDNR. The current version of the form can be obtained at the IDNR website (http://www.in.gov/dnr/water).

This form should be filled out completely for the quickest response. The time required for the IDNR review is often directly affected by the quality of the submitted information.

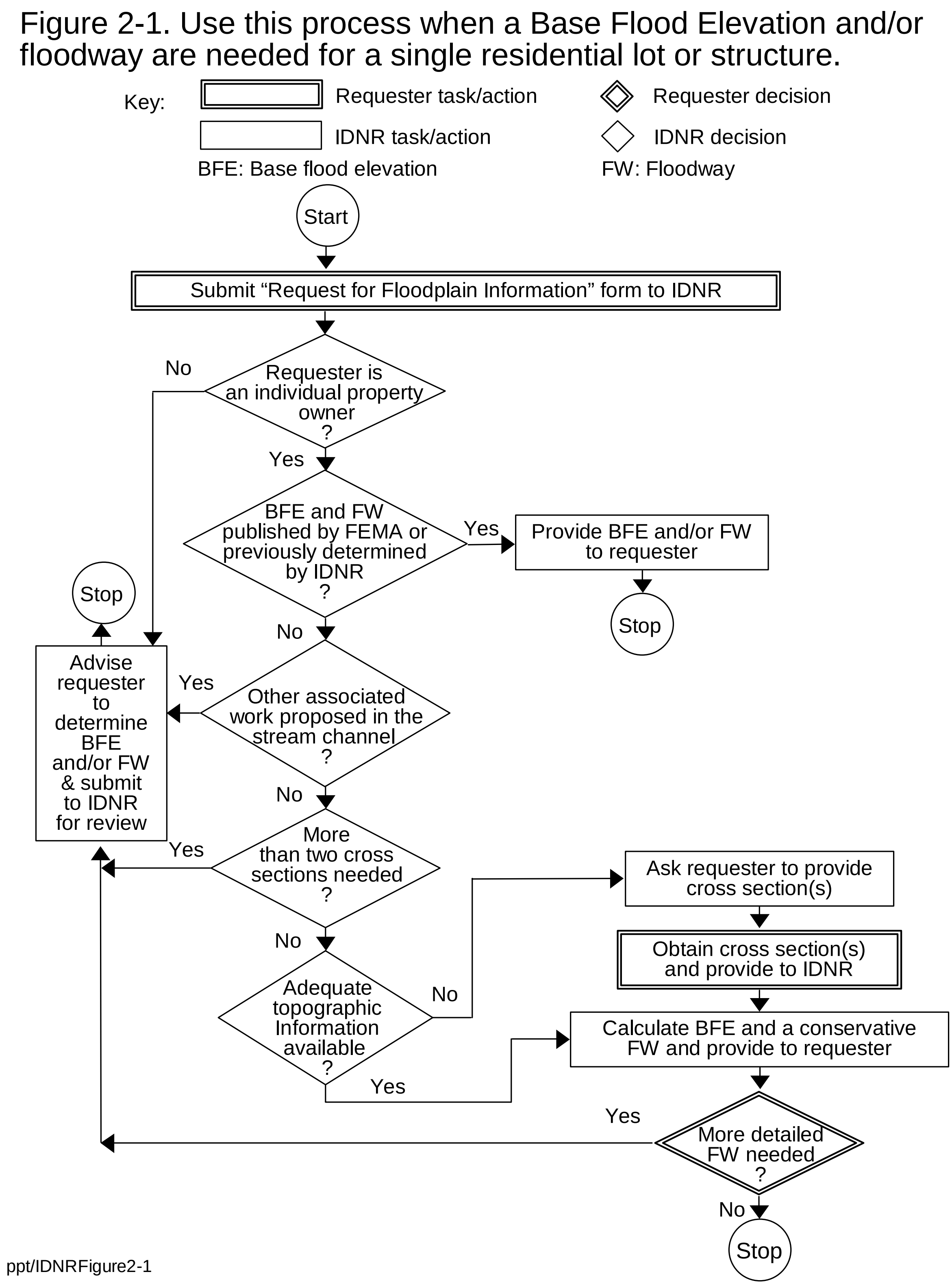
IDNR uses a first come, first served approach in responding to requests. Accordingly, a requester should consult with IDNR personnel to determine if other floodplain requests are pending which may affect that of the requester.

2.3 IDNR Assistance

The IDNR will provide the BFE and floodway limits if the request meets all of the following requirements:

- It is for a single residence and/or out building;
- It is on a single residential lot; and

Figure 2-1. Use this process when a Base Flood Elevation and/or floodway are needed for a single lot or structure.



- No other associated work is proposed in the stream channel, including a driveway stream crossing.

The IDNR uses the “Request for Floodplain Information” form to determine if it will provide the BFE service. If the Department determines, based on the submitted information, that the project does not qualify as a Minor Site Assessment, the requester will be advised to retain an engineering firm to perform the assessment and provide the results to the IDNR for review.

IDNR’s approach to calculating the BFE typically begins with a search for available topographic mapping. The IDNR has access to detailed topographic mapping for certain areas of the state. However, if the requester has access to other detailed mapping, that mapping should be provided to aid in the analysis. If detailed topographic mapping exists for the site in question, then a hydraulic analysis can be done using the mapping. Typically, topographic mapping with a contour interval of four feet is the minimum detail acceptable for use in calculating the BFE for a site.

If mapping is not available, or is inadequate, then the requester will be asked to provide field surveyed cross-section information. IDNR will send a letter and map to the requester specifying the location of the cross-section. Typically, one cross-section is all that is required for a Minor Site Assessment. However, if the site is located upstream of a bridge, then bridge and roadway profile information will also be requested by IDNR, along with one cross-section downstream of the bridge. All survey information should be gathered and presented as described in Chapter 5, “Surveying Standards and Methods,” of these guidelines.

The IDNR will not calculate BFEs for sites that require analyses involving more than two cross-sections if the site is upstream of a bridge or one cross-section if not upstream of a bridge. For a Minor Site Assessment upstream of a bridge or culvert, the IDNR will only calculate BFEs for the site based on one natural full valley cross-section at the project site and one natural full valley cross-section downstream of the existing bridge or culvert crossing in addition to the waterway opening dimensions and top of road profile of the bridge or culvert. If the preceding cross-section numbers are exceeded, IDNR will advise the requester to retain an engineering firm to complete the BFE and/or floodway determination and submit results to the IDNR for review and possible approval.

2.4 Hydrologic-Hydraulic Approach Used by the IDNR

For a Minor Site Assessment, the IDNR will typically calculate a hydraulic rating of a single cross-section. Analyses will include determination of the 100-year peak discharge. The Department will estimate the average friction slope and channel and overbank roughness coefficients, that is, Manning equation “n” values.

Floodway limits cannot be determined using a single cross-section. Where only one cross-section has been used for a site, the floodway will include all land that is below the BFE.

When a bridge or culvert is directly downstream of the site, IDNR will apply a more detailed hydraulic modeling program, such as HEC-RAS, to determine the BFE. In these instances, the floodway will be assumed to include all land that is below the BFE.

If a more precise determination of the floodway is desired, then the site must be evaluated using the methods discussed in Chapter 3, "Performing a Detailed Floodplain Analysis." In such cases, IDNR will advise the requester to retain an engineering firm to perform this calculation and submit the calculations to the IDNR for final approval.

CHAPTER 3

OVERVIEW OF THE PROCESS FOR PERFORMING A DETAILED FLOODPLAIN ANALYSIS

3.1 Purpose

A detailed analysis of floodplains is often necessary to properly plan and prepare for potential flooding conditions. FEMA has published flood insurance studies (FISs) for many areas of Indiana. Some of these are detailed FISs which means that hydraulic analyses were performed and, as a result, detailed floodplain information is available. Other FISs used approximate methods and, therefore, detailed floodplain information is not available.

A community that participates in the NFIP, which involves the majority of Indiana communities, is required to enact and enforce a local floodplain ordinance. That ordinance must meet the requirements of the Indiana Flood Control Act (http://www.in.gov/dnr/water), the Indiana Floodplain Management Act (http://www.in.gov/dnr/water), the Indiana Floodplain Management Rules (http://www.in.gov/dnr/water), and FEMA regulations.

Historically, the IDNR has provided BFEs and floodway limits for proposed developments in unstudied areas, assuming the area of contributing watershed at the development is greater than one square mile. As of July 1, 2002, the Department is requiring that these hydrologic-hydraulic assessments be performed by the requester and submitted to the IDNR for review and approval, unless the situation meets the requirements described in Chapter 2, "Obtaining a Floodplain Determination for a Minor Site Assessment."

As indicated by the preceding, various situations arise in Indiana in which the requester will be asked to perform a detailed floodplain analysis. The purpose of this chapter is to offer guidance on how to complete such analyses. See the IDNR website (http://www.in.gov/dnr/water) for a flow chart, "Overview for Performing a Detailed Floodplain Analysis," summarizing the process described in this chapter. The flow chart is also included as an appendix.

3.2 Gathering Data and Information

An early step in conducting a detailed floodplain analysis is determining if there are existing data and information that would be useful in helping to determine BFEs or floodway limits for the particular stream of interest. Examples of existing data and information are two foot contour mapping, surveyed cross-sections, and computer models previously developed for the stream reach of interest or for adjacent reaches. If a stream crossing is located downstream of or within a proposed project site, state, county, and local records should be reviewed to determine if useful bridge waterway opening or valley cross-section data are available. In some instances, IDNR may have developed computer models for the stream reach being studied or for adjacent reaches. See Chapter 6, "Researching and Evaluating Existing Models," for guidance.

If mapping must be developed for the project site, refer to Chapter 4, "Mapping Standards and Methods" for direction on creating a suitable map. Similarly, if cross-sections and/or bridge and culvert data must be obtained, guidance is offered in Chapter 5, "Surveying Standards and Methods." If discharges are to be determined, refer to Chapter 7, "Guidelines for Determining Peak Discharges." Prior to beginning the hydraulic modeling required for a detailed floodplain analysis, refer to Chapter 8, "Guidelines for Hydraulic Modeling Using HEC-RAS." IDNR prefers use of HEC-RAS for all new hydraulic modeling. However, situations occasionally arise where other hydraulic models may be used. For guidance in these situations, see Chapter 9, "Guidelines for Alternative Hydraulic Models."

3.3 Submitting Detailed Floodplain Analysis to the IDNR

3.3.1 *Hydraulic Modeling Checklist*

IDNR requires inclusion of a properly completed Hydraulic Modeling Checklist with all submittals of detailed floodplain analyses. The Department will not initiate a review without a completed checklist. Refer to Section 10.2 of Chapter 10, "Presentation of Modeling Results," for discussion of the checklist.

Assuming the submittal appears to be complete, it will be assigned to the Engineering Services Center (ESC) of the IDNR Division of Water. The ESC will review the submitted BFEs, floodway, floodplain and 100-year profile using these guidelines.

3.3.2 *Acceptable Submittal*

If the submittal is acceptable, the IDNR will issue a Floodplain Analysis Regulatory Assessment (FARA) letter. The FARA letter will include the accepted BFEs and floodway limits along with regulation requirements for development of the property in question. IDNR will copy the local floodplain management agency on all correspondence related to the detailed floodplain analysis.

3.3.3 *Unacceptable Submittal*

If the ESC determines that the initial submittal is unacceptable, the IDNR will provide the requester with a written description of deficiencies. Although the IDNR expects professionals to provide complete initial submittals, the Department will allow one additional submittal to correct errors and/or rectify deficiencies. If the ESC determines that the second submittal is acceptable, the IDNR will issue the previously described FARA letter. If the second submittal is unacceptable, the IDNR will provide the requester with another written description of the deficiencies; however, this response will also indicate that the IDNR will not review the material again. Therefore, the local floodplain management agency will be unable to issue a building permit. Again, that agency will be copied on all correspondence.

3.4 Possible Revisions to Existing Base Flood Elevations and Floodway Limits

3.4.1 *Needs for Revisions*

Occasionally, previously established BFEs and floodway limits (those appearing in a FIS or resulting from an IDNR approved assessment) need to be reexamined. Examples of situations in which flooding characteristics may be revisited include documented disagreement with previous determinations, changes in watershed hydrology, or influence of a flood control project. Changes to existing studies often require a critical evaluation of the existing study, additional fieldwork to enhance the original model, and remodeling and remapping of the floodplain. Chapters 4 through 10 of these guidelines describe the technical aspects of modeling, which apply to restudies as well as new studies.

3.4.2 *Revisions to Unpublished Studies*

A revision to an unpublished study is treated similarly to the review of a new floodplain analysis as described in Sections 3.1 and 3.2 of this chapter. IDNR is looking for the same types of items that a new study would have, including the checklist. Examination of the previous review material in IDNR's files can be helpful in evaluating and updating a previously approved model. IDNR's review process for these requests is the same as for new requests. A FARA letter will be the end result of the acceptance of a study of this type.

Proposed revisions to the 100-year peak discharge are evaluated based on the options and procedures described in Chapter 7. Review this chapter carefully before beginning to revise existing hydrologic results because many aspects of floodplain hydrology as viewed by the IDNR differ from stormwater hydrology as reviewed by local government entities.

Revisions to the floodway should be done in accordance with the hydraulic modeling guidelines provided in Chapter 8. Two criteria are especially important. First, the floodway revision should be based on equal conveyance reduction (Method 4 in HEC-RAS modeling). Second, the floodway must be based on pre-project conditions unless an IDNR-approved flood control project would result in changes to those limits.

3.4.3 *Revisions to Published Studies*

The process to revise a FIS is referred to as a Letter of Map Revision (LOMR). LOMR application forms (referred to as the MT2 forms) are available on the FEMA website (http://www.fema.gov/). Required modeling submittals are explained in Section 3.5 of this chapter, while the process for review and approval of a LOMR is described in Section 3.7 of this chapter.

3.5 Models Required for IDNR Approval of a Permit or Map Revision Request

3.5.1 *Defining the Study Reach*

The total study reach, or the area of revision, is defined by an effective tie-in or transition of the reach of interest with reaches immediately upstream and downstream. For streams that require a detailed study, the study reach should begin downstream at a point where there is currently no cumulative flood surcharge effect from previously permitted or allowed floodway encroachments, or where the cumulative flood surcharge effect from previously permitted or allowed encroachments is known. The study reach should extend upstream, at a minimum, to the point where there are no remaining flood surcharge effects from the proposed floodway encroachment for the project in question.

The following equation, taken from USACE Hydrologic Engineering Center - Technical Paper No. 114, can be used to estimate the distance upstream or downstream the study reach should extend to adequately account for cumulative effects and to estimate a point to tie-in to an existing profile.

$$\mathbf{L=150\ HD^{0.8} / S}$$

Where,

L is the reach length in feet,

HD is the average hydraulic depth for the assumed 100-year frequency flood profile through the project reach in feet (cross sectional flow area in ft^2 divided by top width in feet), and

S is the average reach slope in percent (e.g., feet per 100 feet).

Revisions of both the downstream and upstream extents of the study reach may be necessary if additional flood profile information becomes available during preparation of a detailed flood study. IDNR staff should be contacted to consider allowing a shorter study reach if the applicant believes the required study reach is excessive in light of the fact that the surcharges are consistently decreasing upstream and that potential for unacceptable cumulative impacts upstream is unlikely in a particular situation.

If a floodway revision is proposed, the effective encroachment stations and floodway top widths should tie-in at both the upstream and downstream limits of the project reach. As indicated by the preceding, the total reach requiring study will always be longer than the reach containing the project.

3.5.2 *Duplicate Effective Model*

When a detailed FIS or LOMR model exists, copies of the hydraulic analysis used in the effective FIS, referred to as the Effective FIS Models (10-, 50-, 100-, and 500-year multi-profile runs and the floodway run), must be obtained from the IDNR or FEMA and then reproduced on the applicant's equipment to produce the Duplicate Effective Model. This duplication process ensures that the Effective FIS Model input data have been correctly transferred to the applicant's equipment and that revisions to the data will be integrated into the model to provide a continuous FIS model upstream and downstream of the reach being revised.

The IDNR maintains digital copies of most detailed FIS hydraulic models either developed by IDNR or submitted for their review. The Department has an index of all models in its files available to download. Go to the IDNR website (http://www.in.gov/dnr/water).

Sometimes the published BFEs and floodway limits cannot be duplicated by current modeling software. If the Effective FIS Models cannot be rectified adequately with the corresponding FIS mapping and the Floodway Data Table, the requester must either modify or generate a new model that duplicates the FIS profiles and the elevations shown in the Floodway Data Table in the FIS report to within 0.10 foot or contact IDNR for further guidance.

IDNR also maintains a number of IDNR-approved detailed hydraulic studies that may have not yet been published by FEMA as a detailed study or used by FEMA to update the published information. While IDNR views these as Regulatory Models, they may or may not be viewed by FEMA as Effective Models.

IDNR usually accepts FEMA's most current Effective FIS Model as the IDNR Regulatory Model. However, in rare circumstances and to meet the IDNR baseline condition modeling requirements, an alternative hydraulic model in the form of an unpublished Corrected Effective Model may have been developed and considered as a Regulatory Model for the IDNR regulatory purposes. Therefore, the applicant is encouraged to consult the IDNR staff to ensure that the applicable Effective FIS Model has been accepted by the IDNR as the Regulatory Model for permitting purposes. Unless IDNR has an approved Corrected Effective Model, the Effective FIS Model would serve as the regulatory model for IDNR permitting purposes.

3.5.3 *Corrected Effective Model*

The Corrected Effective Model is the model that corrects any errors that occur in the Effective FIS Model, adds any additional cross-sections to the Effective FIS Model to properly analyze the impact of the proposed construction, or incorporates more detailed topographic information than that used in the effective model. An error could be a technical error in the modeling procedures or any construction in the floodplain that occurred prior to the date of the Effective FIS Model but not incorporated into the model. Before adding the effects of any construction, the IDNR staff should be consulted to ensure that such construction meets the Floodplain Management Rules.

For the purpose of an IDNR Construction in a Floodway Permit, the Corrected Effective Model will be considered to represent the base conditions. Except for incorporating the effects of IDNR-approved Flood Control Projects, the Corrected Effective Model must not reflect any man-made physical changes since the date of the effective regulatory model. If no corrections or additions to the Effective FIS Model are needed, then the Effective FIS Model would be considered the Corrected Effective Model.

When a published detailed FIS/LOMR model or an unpublished IDNR Regulatory Model does not exist, a base condition hydraulic model meeting the IDNR requirements must be produced and submitted. Base conditions are defined by the Floodplain Management Rules as the physical situation existing on January 1, 1973. The model of base conditions is used to define the regulatory floodway. If the topography that existed on January 1, 1973 cannot be reasonably determined, then the best available mapping developed from data collected on the closest date after that should be used to develop the base model. Chapters 4 and 5 explain the process to be used for getting the best available data. The base condition includes all flood control projects approved under IC 14-28-1-29 in the Indiana Flood Control Act or otherwise formally recognized as flood control projects by the IDNR.

When a bridge has been replaced in compliance with state statute and IDNR rules since January 1, 1973, the more efficient bridge configuration should be used in the base model. The more efficient bridge is defined as the one that causes the smaller surcharge across the bridge. If a bridge replacement has not been in compliance with state statute and IDNR rules since January 1, 1973, the bridge that existed on the stream on January 1, 1973 should be included in the baseline model.

3.5.4 *Existing or Pre-Project Condition Model*

The Effective FIS Model or Corrected Effective Model is modified further to produce the Existing or Pre-Project Condition Model. This model reflects modifications that occurred within the floodplain since the date of the Effective FIS Model but prior to the construction of the project for which the permit or revision is being requested. If no modifications have occurred since the date of the effective model, then the Existing or Pre-Project Condition Model would be identical to the Corrected Effective Model.

State regulations and administrative rules require that cumulative effects of the action for which a permit is being sought be added to other past, present, and reasonably foreseeable future actions, regardless of what entity undertakes the other actions. Therefore, the Existing or Pre-Project Condition Model should include the above-noted actions, excluding the action for which the permit is being sought, so that cumulative effects may be properly evaluated.

The typical procedure for development of an Existing or Pre-Project Condition model is as follows:

- The Effective FIS Model or IDNR Regulatory Model is obtained from IDNR's website, if available. If no such model currently exists, the modeler must develop a Corrected Effective Model for the project site from detailed contour mapping or surveyed cross-sections.
- Necessary modifications and corrections are performed to develop the Corrected Effective Model.
- The modeler researches IDNR files for Construction in a Floodway Permits issued for any other nearby projects that may result in backwater effects within the study reach of the stream or river.
- Based on this research, the modeler then obtains available flood models developed and submitted for these projects from IDNR files or website.
- The modeler then conducts a field investigation to determine if the permitted projects were indeed constructed and, if so, were constructed as permitted. The modeler should also determine if any unpermitted projects have been constructed and whether as-built surveys need to be conducted at any location.
- The modeler, using the procedures outlined in this chapter, would then put together the Existing or Pre-Project Condition model.
- The modeler should note in the Existing or Pre-Project Condition Model what cross-sections were incorporated from previously approved or accepted flood models.

3.5.5 *Proposed or Post-Project Condition Model*

This model includes the pre-project conditions plus the proposed or post-project modifications. The Existing or Pre-Project Condition model (or Effective FIS Model or Corrected Effective Model, if appropriate) is further revised to reflect post-project conditions. The Proposed or Post-Project Model must incorporate everything included in the Existing or Pre-Project Condition Model plus the proposed or post-project conditions.

Similar to the Existing or Pre-Project Condition Model, for IDNR permitting purposes, the Proposed or Post-Project Model must reflect the impact of cumulative effects as defined in IDNR regulations and administrative rules.

3.6 Applications for Proposed Construction in a Floodway

This section provides guidance on preparing an application to obtain a permit for construction in a floodway. Detailed information on this permit process is available at the IDNR website (http://www.in.gov/dnr/water). Types of construction in floodway projects that do not require modeling are described at the noted website. Therefore, consult the website to avoid needless modeling efforts.

Modeling submitted in support of a construction in a floodway permit application is reviewed and evaluated by the ESC. The previously mentioned modeling checklist must be included with the submittal. Models submitted without a completed checklist will not be reviewed. The permit application will be placed in abeyance and the applicant notified that the application will be denied if a completed checklist is not submitted within ninety (90) days. Upon the review of the submitted checklist and modeling, the ESC will draft a technical memorandum recommending either approval or denial of the project, or asking for corrections to the modeling before a conclusion can be reached. Refer back to Section 3.3; the same principles and procedures apply.

For IDNR approval, the requester must demonstrate that the project will not, either individually or in combination with other past, present, and reasonably foreseeable future actions, increase the BFE by more than 0.14 feet outside the requester's property. This is calculated by comparing the elevations from the Proposed or Post-Project Condition Model with the Existing or Pre-Project Condition Model as well as with the Corrected Effective Model, or with the Duplicate Effective Model, if no enhancements/corrections were performed. Figure 3-1 depicts a sample Project Evaluation Table, which should be included in the submittal package.

In some cases, the Existing or Pre-Project Condition model will show base flood elevations that exceed the 0.14-foot threshold as compared to the Corrected Effective Model. In these circumstances, IDNR staff should be consulted prior to

Figure 3-1. A project evaluation table like this should be included with an application for a construction in a floodway permit.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
LOCATION DESCRIPTION		PUBLISHED OR EFFECTIVE DATA (Ft., NGVD) (Based on FIS Table, LOMR, or Profile)	MODELING RESULTS				COMPARISONS*			NOTES
Model Cross Section	Location Description		Duplicate Effective Model (Ft., NGVD) (File/Plan Name)	Corrected Effective Model (Ft., NGVD) (File/Plan Name)	Existing/ Pre-project Model (Ft., NGVD) (File/Plan Name)	Proposed/ Post-project Model (Ft., NGVD) (File/Plan Name)	Cumulative Impacts w/o Project (ft) (6) - (5)	Cumulative Impacts with Project (ft) (7) - (5)	Project Impacts (ft) (7) - (6)	
	D/s end of the study reach									
	...									
	...									
	...									
	D/s property limit									
	...									
	...									
	Example Road									
	...									
	...									
	...									
	...									
	U/s property limit									
	...									
	...									
	...									
	U/s end of the study reach									

NOTES:

* Project is considered permittable if maximum surcharges outside the property are no more than 0.14 feet in both columns (9) and (10). If the maximum surcharge outside the applicant's property exceeds 0.14 feet in columns (8) and (9), the project may still be permittable if the project impacts shown under column (10) do not exceed 0.00 feet outside the applicant's property.

submitting an application. The IDNR may still grant a permit to the applicant if it can be shown that the project for which the permit is being requested, as modeled in the Proposed or Post-Project Condition Model, would cause no increase over the Existing or Pre-Project Condition Model.

Project surcharges greater than 0.14 feet are acceptable if the extent of the excessive surcharge remains on the requester's property. Proof of property ownership is required in these cases. Flood easements might be obtained for off project land that would be inundated by an excessive increase in regulatory flood stages. However, the project for which an easement is permitted must be a dam, a flood control project as defined under IC 14-28-1-29, or a public works project. See Section 3.8 for further discussion of flood control projects. If base flood elevations (as published by FEMA) are being exceeded in these instances, then a Conditional Letter of Map Revision (CLOMR) is required before the IDNR can issue an approval of the project. See Section 3.7 for more information on the CLOMR application process.

3.7 Applications for FEMA Letters of Map Revision

In some instances, there may be a need to revise the effective Flood Insurance Rate Map (FIRM) for an area, based on a project or updated information for a stream. Map changes that do not involve a revision to the BFEs or to the floodway limits such as flood fringe redelineations, LOMAs, and Letters of Map Revision based on fill (LOMR-F's), usually do not need to be reviewed by IDNR for concurrence. However, proposals to revise BFEs or floodway limits will, in most cases, need to be reviewed and approved by the IDNR.

A Letter of Map Revision (LOMR) is an official revision, by letter, to an effective NFIP map. A LOMR may change flood insurance risk zones, floodplain and/or floodway boundary delineations, planimetric features, and/or BFEs. All requests for LOMRs must be supported by detailed flood hazard analyses prepared by a qualified professional engineer. The specific data and documentation requirements are contained in Part 65 of the NFIP regulations and in FEMA's application/certification forms (MT-2). To defray costs to NFIP policyholders, FEMA charges fees to recover review costs. Specific information on the fee schedule and exemption requirements is contained in the MT-2 forms.

Because the Indiana Floodplain Management Rules state that all changes to floodways and BFEs be approved by IDNR, LOMR applications should be submitted to IDNR for review before they are submitted to FEMA. IDNR's review of and concurrence with a potential LOMR is not required if the stream in question has a drainage area of less than one square mile. However, if the potential LOMR submittal involves a proposed change in the hydrologic analysis affecting points on streams or lakes having a contributing watershed area greater than one square mile, the hydrologic analysis requires IDNR approval. Contact the IDNR for guidance in these cases.

Certification by a registered professional engineer or land surveyor is required by FEMA for a LOMR. In addition, a local community official must indicate in writing that they have reviewed the request and understand its implications on flooding in their community.

A CLOMR is FEMA's comment on a proposed project that would affect the hydrologic and/or hydraulic characteristics of a flooding source and thus result in the modification of the existing regulatory floodway or effective BFEs. A CLOMR comments on whether the proposed project meets the minimum floodplain management criteria of the NFIP and, if so, what revisions will be made to the community's NFIP map if the project is completed as proposed.   The submission requirements for a CLOMR are similar to the requirements for a LOMR. For the conversion of a CLOMR to a LOMR, as-built plans for the project must be submitted to FEMA for their review and approval. IDNR review of the as-built plans is not necessary unless the plans are different enough from the initial CLOMR that BFEs or floodway limits are affected.

Submission requirements for IDNR review and approval of a CLOMR or LOMR are similar to the requirements for other model reviews. The previously mentioned modeling checklist must be included with the submittal. Models submitted without a completed checklist will not be reviewed. The IDNR will take no further action on the CLOMR or LOMR request until a completed checklist is submitted. Upon the review of the submitted checklist and modeling, the ESC will draft a technical memorandum recommending either approval or denial of the revision, or asking for corrections to the modeling before a conclusion can be reached. Refer back to Section 3.3; the same principles and procedures apply. FEMA's review is expedited if the approval letter and the technical memorandum are submitted to FEMA with the application packet.

Another type of Map Revision is a Physical Map Revision (PMR). Usually this involves a major restudy and the establishment of FEMA recognized BFEs. These types of studies involve republishing the maps and the FIS text, and take considerably longer to complete due to the complexity of the project and FEMA's public notice requirements. If this type of map revision is being considered, the requestor should initiate coordination with ESC staff well in advance of any submittals.

3.8 Flood Control Projects

A flood control project is a work of any nature that is designed, constructed, and operated according to sound and accepted engineering practice for flood control. Typically, these projects may include reservoirs, detention or retention ponds, channel improvements, or levees. For the effect of these types of projects to be considered for establishing BFEs or floodway limits, both of the following conditions apply.

- The project must be approved under the Flood Control Act (IC 14-28-1-29) or constructed by the U.S. Army Corps of Engineers (USACE) as a flood control project.

- The project must be properly operated and maintained by a governmental entity. An operation and maintenance agreement signed by the appropriate official is required.

3.9 Levees

The following conditions must be met for the area protected by a levee to be removed from the 100-year floodplain:

- The levee must be approved as a flood control project under the Flood Control Act (IC 14-28-1-29) or be constructed by the USACE as a flood control project to remove areas from at least the 100-year floodplain.

- FEMA requires that the levee must have a minimum of 3.0 feet of height above the BFE. 4.0 feet of freeboard are required within 100 feet of either side of appurtenant structures such as gates, pump stations, and walls. 3.5 feet of freeboard are required at the upstream end of the levee, tapering to 3.0 feet at the downstream end of the levee. Exceptions to the minimum freeboard requirements may be considered, but under no circumstances will less than 2.0 feet of freeboard be accepted.

- Embankment protection, embankment and foundation stability and settlement, and any other site specific geotechnical issues must also have been analyzed and addressed.

- Interior drainage analysis is required. Any flooding that would result from lack of capacity of the interior drainage system must be mapped as regulatory floodplain. This analysis is not required by IDNR, but is required by FEMA under 44 Code of Federal Regulations (CFR) 65.10.

- Written operation and maintenance plans must be prepared for levees, levee closures, and interior drainage systems. These plans must be officially adopted, managed, and implemented by one or more local government entities.

For levees that meet the preceding conditions, the floodway limit is drawn at the landward toe of the levee. The area of floodplain that is removed is shown as “Shaded Zone X”, which means that while these areas are not considered regulatory floodplain, they are shown as being “at-risk”.

If a levee does not meet the preceding requirements, elevations streamward of the levee should be determined assuming that the levee will be in place during the 100-year frequency flood. Elevations outside of the levee should be determined without considering the levee, that is, assuming that the levee will fail. Generally, floodways are calculated without considering the levee. However, on a case-by-case basis, and depending on the height and conditions of the levee, IDNR may allow the levees to be considered for floodway determination.

CHAPTER 4

MAPPING STANDARDS AND METHODS

4.1 Purpose

An important result of a floodplain hydrologic-hydraulic assessment is a plot of the floodplain and floodway on a suitable map. While different types of mapping may be available, most mapping does not provide the detail needed to accurately depict flooding hazards. The purpose of this chapter is to offer suggestions for selecting or creating a map suitable for plotting floodplain and floodway limits.

4.2 Sources of Existing Mapping

4.2.1 *IDNR "Floodplain" Mapping*

Typically, IDNR mapping is at a horizontal scale of 1" = 200' with a contour interval of two feet. An index to these maps appears on the IDNR website (http://www.in.gov/dnr/water). Because these maps were specifically created for delineating floodplain and floodway boundaries, they are ideal for use as base maps. These maps cover many of Indiana's major urban streams. While these maps are ideal for establishing base conditions, they may not be suitable for existing conditions. Many of these maps were prepared in the 1960's and 1970's, thus, many of their features may be outdated. Refer to the top of the previously mentioned IDNR website Publications List for map ordering information.

4.2.2 *County or City Mapping*

Many county and city governments are developing their own sources of mapping for use in local zoning, planning, and engineering activities. While these maps vary in horizontal scale and contour interval, they usually meet IDNR "Floodplain" mapping standards.

IDNR has an index to county and city mapping on the IDNR website (http://www.in.gov/dnr/water). IDNR does not distribute county and city mapping. Therefore, potential users are asked to contact local planning, engineering, surveying, or other appropriate offices to learn more about and possibly acquire county and/or city maps.

4.2.3 *FEMA Workmaps*

FEMA often has detailed contour mapping (known as workmaps) created for use in Flood Insurance Studies. In the past, FEMA's minimum standards for their mapping has been a horizontal scale of 1" = 400' with a contour interval of four feet. Recently, FEMA has adopted more detailed standards for floodplain mapping. However, these older FEMA workmaps may be suitable for plotting floodplain and floodway limits.

In fact, since these maps were used in the production of the FIS, they may have the floodway and floodplain drafted on them, but beware: occasionally the flood information themes or layers on these maps have been subsequently changed for final publication of the FIS. Maps in the FIS are the final authority on floodplain and floodway limits.

Copies of various FEMA workmaps are available from the IDNR. For an index, refer to the IDNR website (http://www.in.gov/dnr/water) which includes information on obtaining copies of these maps. This may not be a complete list of FEMA workmaps, since some maps have been lost. Refer to the FIS text to determine what base mapping was used in the creation of the FIS maps.

4.2.4 *Local Development Project Plans*

Public works and other projects often include the development of maps. Examples of such projects are storm and sanitary sewer systems, roads and bridges, subdivisions, water and wastewater treatment plants, and industrial/commercial developments. These maps may be suitable for plotting floodplains and floodways. However, because these maps were not specifically created for floodplain use, they must be examined carefully for contour suitability, horizontal and vertical datums, and the overall accuracy.

4.2.5 *Ohio River "Strip Mapping"*

The USACE created this mapping in the mid 60's for the Ohio River and the overbanks. Arranged by pool reach, this mapping has a horizontal scale of 1" = 600' and the contour interval is five feet (with some 2 ½ foot supplemental contours). The vertical datum of the elevation data on these maps is the Sandy Hook Datum; not the National Geodetic Vertical Datum (NGVD) of 1929. The appropriate conversion from Sandy Hook Datum to NGVD 1929 is available by request from the IDNR's Surveying and Mapping Section.

4.2.6 *Other Historic Mapping*

Other "strip" mapping exists for major rivers in Indiana such as the Wabash, White and East Fork White. However, this mapping is typically much older than the Ohio River mapping (dating from the 30's in many cases) and, therefore, is only useful for historical purposes. The Corps of Engineers also compiled mapping for use in design of the major reservoirs in the state, including a couple (Lafayette and Big Pine) that were never constructed. These maps are officially out of print, but copies can be made of maps in IDNR files by contacting the Public Information and Outreach Section.

4.2.7 *Digital Orthophoto Quadrangles (DOQ)*

DOQs are digital, georeferenced aerial photographs that have been published by the U.S. Geological Survey (USGS) and are available for the entire state. These photos are taken at a scale of 1" = 1000' and contours are not available. The DOQs are the minimum standard suggested for acceptable mapping by FEMA and IDNR for floodplain use. Many applications require the use of mapping more accurate than DOQs for acceptable floodplain and floodway determinations. For additional information on DOQs, refer to a USGS website (http://mapping.usgs.gov).

4.2.8 *USGS 7 ½ Minute Quadrangles*

These widely known and used maps have a horizontal scale of 1" = 2000' and, in Indiana, a contour interval of 10 feet. While USGS 7 ½ minute quadrangles are ideal locating and planning tools, along with being the most suitable maps for watershed delineation and hydrology studies, they should only be used for delineation of floodways and floodplains if more detailed mapping is not available.

USGS Quadrangle maps can be obtained from the IDNR map sales office. They are also available in a digital format from the USGS and from many third party vendors. (For example, go to the USGS website, http://mapping.usgs.gov).

4.2.9 *Digital Elevation Models (DEMs) and Triangulated Integrated Networks (TINs)*

A DEM or a TIN is not a traditional paper map but is instead a series of points that are used in a Geographic Information System (GIS) or in Computer Aided Drafting (CAD) as a numerical representation of the earth's surface. Digital contour information is often derived from these networks. However, if the DEM or TIN is of sufficient density and accuracy to create quality contour information needed to derive cross-section information, in most cases, the cross-section could be taken directly from the DEM or TIN information. Any number of graphical computer packages (such as HEC-GeoRAS) can be used to derive cross-section information in this manner.

A common source for DEM data is the USGS 30 meter DEM that can be downloaded from the USGS website (http://mapping.usgs.gov). These data are fairly crude, however, and therefore are generally acceptable only for very preliminary hydraulic studies. Hydraulic models derived using such data should be marked clearly, so that a subsequent user does not get the false impression that data contained within the model has a high degree of accuracy.

4.3 Site Specific Topographic Mapping

If an adequate site map does not exist for a floodplain and floodway study, then an option is to develop a site specific map for use in determining and plotting flood themes or information. Additionally, the nature of the project may require that detailed site topography be obtained for other uses (e.g., grading, site layout, and utilities). Therefore, in the planning stages of a project, the compilation of adequate data for floodplain mapping is one of the considerations in the overall tasks for and costs of a project.

From the perspective of the IDNR, some factors to consider when planning site specific mapping are:

- For large scale residential, commercial and industrial projects, mapping should be obtained at a minimum of the standard used for IDNR floodplain mapping, that is, a horizontal scale 1" = 200', and a contour interval of two feet. These types of projects are where severe flood losses could occur and inaccurate mapping may lead to understatement of flood risks and/or improper land use. The floodway delineation process, in particular, becomes clearer and easier when quality mapping is used. The indicated scale and contour standards should also be used for the planning of water related projects (e.g., wastewater treatment plants, regional detention ponds, and levees). If possible, the mapping should extend beyond the point of interest, so that downstream starting elevations and upstream effects can be properly analyzed.

- Smaller scale developments (i.e., five lots and/or five acres or less) typically do not need mapping as detailed as that required for larger scale developments. Judgment should be used in determining the optimum scale and contour interval, weighing the cost of the mapping versus the actual potential for flood damage in the area being considered. Single lot residential and small commercial and industrial developments could use DOQs for mapping a floodway, with cross-section data taken in the field and plotted on the map.

- Consideration should be given to floodplain areas for which detailed mapping is not available, but which have been identified as having the potential for high development. Developers should consider working with the local community in a cooperative mapping effort, to both minimize costs and encourage mapping uniformity.

CHAPTER 5

SURVEYING STANDARDS AND METHODS

5.1 Purpose

The accuracy of BFE calculation and of floodplain and floodway delineation is highly dependent on the planning and conduct of field surveying. Of particular importance are benchmarks, location and orientation of channel-floodplain cross-sections, and acquisition of bridge and culvert information. The purpose of this chapter is to set forth surveying standards and suggest surveying methods likely to lead to determination of BFEs and plotting of floodways and floodplains that are acceptable to IDNR.

5.2 Plans to be Submitted with Cross-Section Data

Plans should be prepared under the supervision of a land surveyor or engineer with knowledge of generally accepted survey principles. When FEMA approval is required, surveying must be performed under the direction of a licensed surveyor. Show features such as the following on the plan:

1. North arrow
2. Scale in both numerical and graphic format.
3. Horizontal and vertical control benchmarks used. For additional benchmark guidance refer to the section in this chapter titled “Guidelines for Survey Benchmarks.”
4. Horizontal and vertical datums.
5. Property limits; approximate boundaries are acceptable, unless flood surcharges exceed 0.14 feet at any point, in which case accurate boundary locations are required.
6. Existing and, as appropriate, proposed contours.
7. Rivers or streams and other water features.
8. Streets and roads.
9. Existing and proposed features such as buildings, parking lots, woodlands, and parks.

10. The full extent of each surveyed channel-floodplain cross-section, that is, location, orientation, and end points. Indicate the zero or other starting station.

Station-elevation data for each cross-section should be submitted in tabular and graphical form (cross-section plots). For each surveyed point defining the cross-section, the cross-section table should indicate distance and elevation with the latter referenced to an acceptable vertical datum.

5.3 Guidelines for Location and Orientation of Cross-Sections

The IDNR prefers that full valley cross-sections be developed from detailed topographic mapping but recognizes that this may not always be practical or economically feasible. When justified, individual cross-sections may be used in lieu of detailed topographic mapping. Cross-section location and orientation should be discussed by the engineer responsible for the floodplain hydrologic-hydraulic assessment and the surveyor responsible for obtaining the cross-section data. Pre-survey discussion and coordination between engineer and surveyor are necessary because cross-section surveys which provide input to hydrologic and hydraulic computer models are very different than those obtained for highway and other projects.

Figure 5-1 is a plan view of a hypothetical channel-floodplain reach. Included are typical cross-sections, each of which is numbered. Figure 5-1 is used to illustrate some of the following guidelines for locating and orienting channel-floodplain cross-sections. More specifically, consider the following:

1. Give each cross-section a unique name or label, preferably mile station upstream of the mouth of the river or stream.

2. Select each cross-section so that it represents “average” conditions for a reach. For example, ignore isolated depressions, ponds, and other similar features. However, include objects or features that will significantly restrict flow.

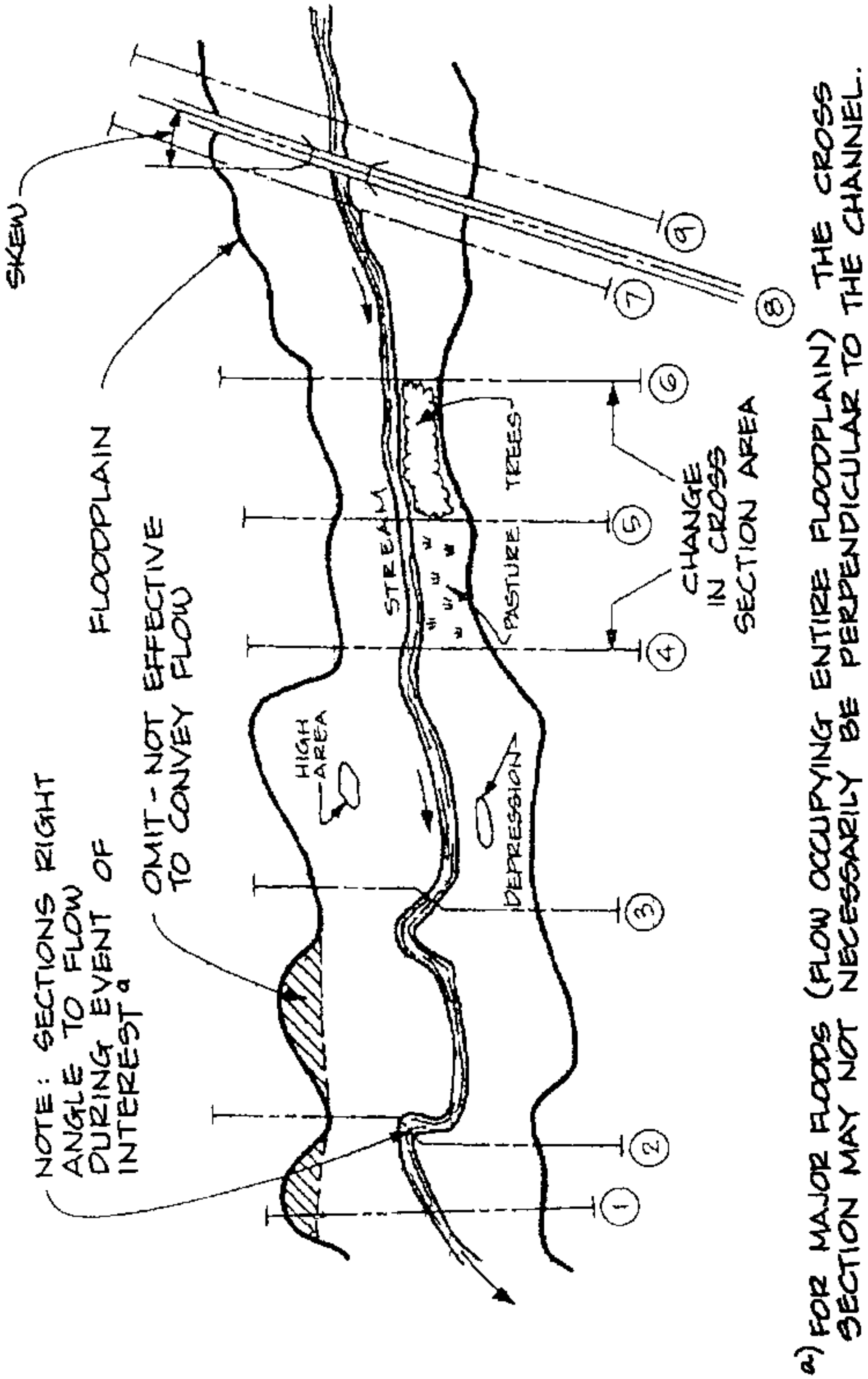
3. Place cross-sections at changes in longitudinal slope of the channel and/or floodplain.

4. Locate cross-sections at positions coincident with cross-sections used in previous floodplain studies to facilitate comparison of computed stages.

5. Cross-sections should never cross or intersect each other.

6. Place cross-sections at those locations where high water marks are available so that computed and observed flood stages can be compared.

Figure 5-1. Cross-section location guide



Source: Walesh, 1989; Lee, 1968

7. Place cross-sections immediately upstream and downstream of any culvert or bridge. If the roadway is built on an embankment, the cross-sections should be just outside the toe of the fill and the side ditch. If this is impractical, or the roadway does not appear to be higher than the adjacent ground upstream and downstream of the bridge/culvert, then the cross-sections should be taken at the culvert/bridge faces.

8. Locate cross-sections at county, city, and town and other corporate boundaries. Do this in anticipation of neighboring jurisdictions being concerned with possible stage increases as a result of floodplain development. Placing cross-sections at corporate limits facilitates responding to these inquiries.

9. Consider possible sites of future development in locating channel-floodplain cross-sections. For example, cross-sections should be located at planned or anticipated residential or commercial areas, parks, highways, and other floodplain developments. Placing cross-sections at these locations facilitates future evaluation of the hydraulic impact of proposed floodplain fill or other alterations.

10. Avoid placing cross-sections where they would intersect tributary swales and ravines.

11. Extend cross-sections left and right so that they represent the total area likely to convey discharges up to at least the 100-year peak discharge. These are known as full valley cross-sections.

12. Orient the cross-section in plan so that all segments are perpendicular to flood flow. Angles and “dog legs” are likely to occur.

13. Take and present cross-section data from left to right across the valley with the left end or starting point being defined by looking downstream.

14. Include points at changes in grade across the cross-section.

15. Note how the stream bed portion of the cross-section was defined. Some possibilities are directly measuring, with a tape, rod or other method, and estimating the average depth to the bottom from the water surface. If average depth was estimated, explain how.

16. Indicate, on the plotted cross-section, the general ground cover observed in the channel, on the banks and on the floodplains.

    - Suggested channel ground cover categories: concrete, clean, some stones or weeds, large rock or weedy, very weedy, heavy timbers and brush, deep pools, and other as specified.

- Suggested bank ground cover categories: grass, agricultural or light brush, medium brush and trees, heavy brush or many downed trees, and other as specified.

- Suggested floodplain ground cover categories: grass, agricultural or light brush, medium brush and trees, heavy brush or many downed trees, buildings, and other as specified.

5.4 Guidelines for Survey Benchmarks

Topographic data must be referenced to one or more accepted permanent benchmarks, such as those established by the National Geodetic Survey, USGS, or IDNR. Other benchmarks may be used provided supporting documentation is submitted which supports a tie back into a previously recognized benchmark. Wherever practical, use of more than one benchmark is recommended to provide a check on the elevations.

Measurements should be referenced to NGVD 1929 or North American Vertical Datum (NAVD) of 1988. If the project is along the Ohio River or shoreline of Lake Michigan, contact the IDNR regarding the appropriate datum to use.

A description of the specific benchmark used in the survey, including benchmark location, should be included as a note on the plan view map. Questions regarding benchmark information should be directed to the IDNR Surveying & Mapping Section.

5.5 Guidelines for Bridge and Culvert Information

Four photographs, two of bridges and two of culverts, are presented in Figure 5-2. The photographs suggest locations at which station-elevation data should be taken to define bridge and culvert cross-sections. More specific guidance follows.

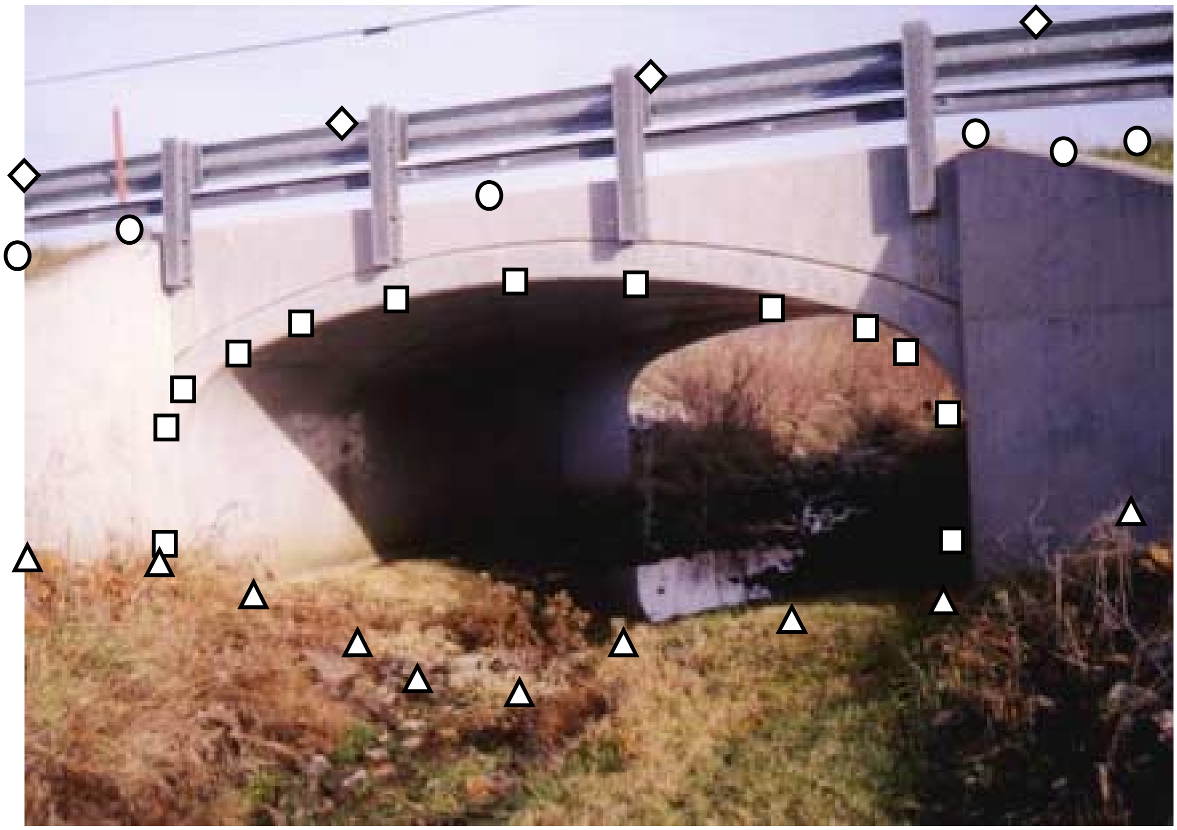
5.5.1 *General Information for both Bridge and Culvert Sections*

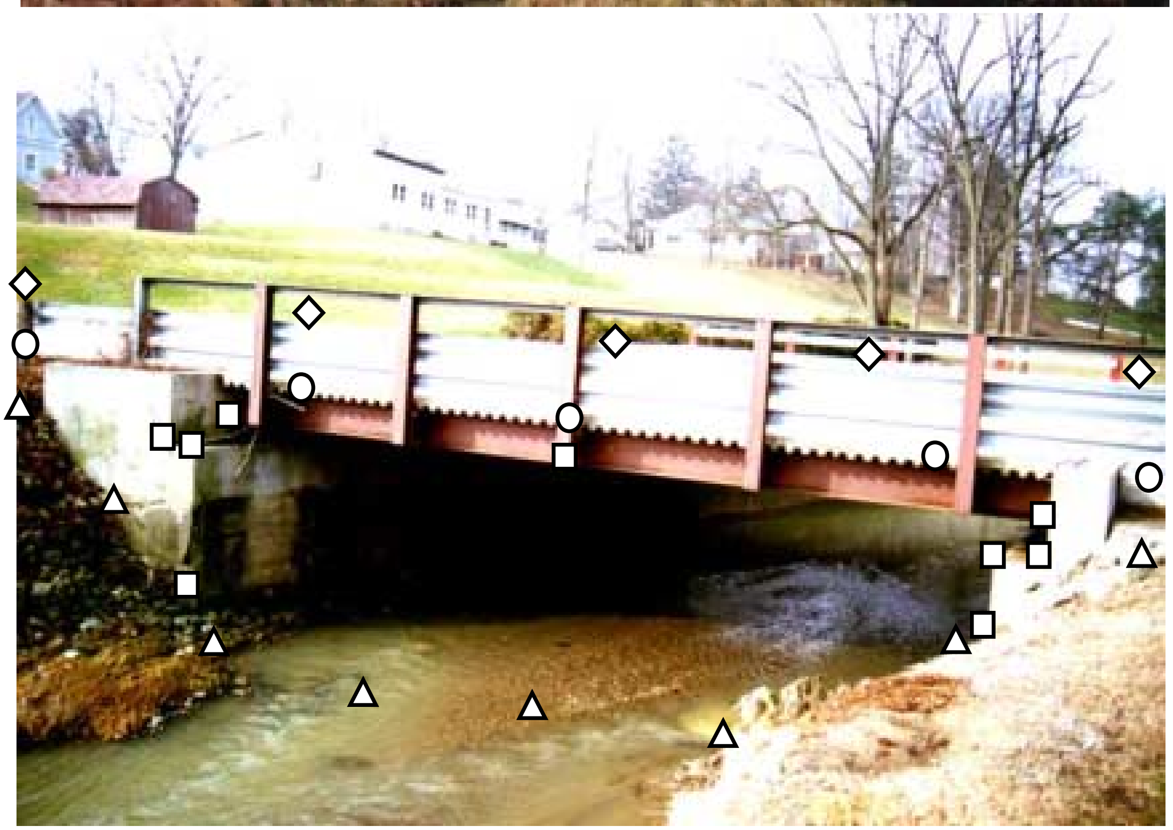
- Bridges and culverts require valley sections at or near the upstream and downstream faces of the structure.

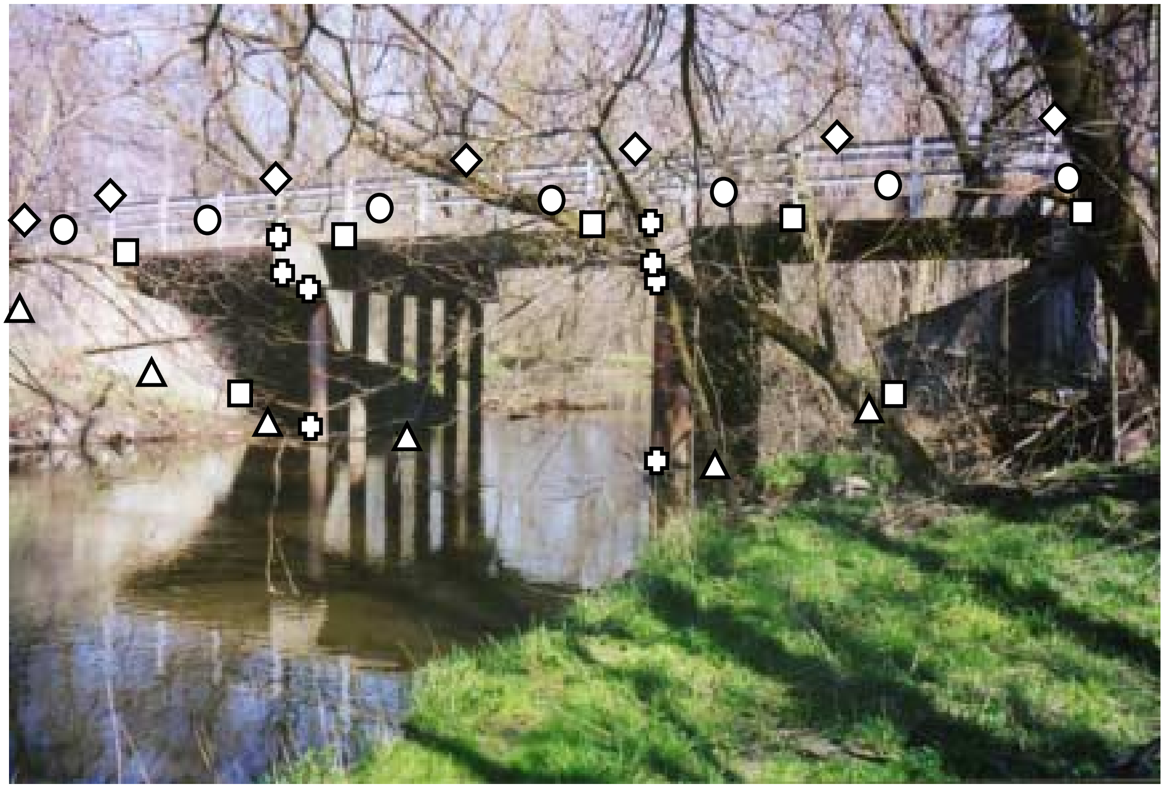
Figure 5-2. Suggested locations at which station-elevation data should be taken to define bridge and culvert cross-sections.

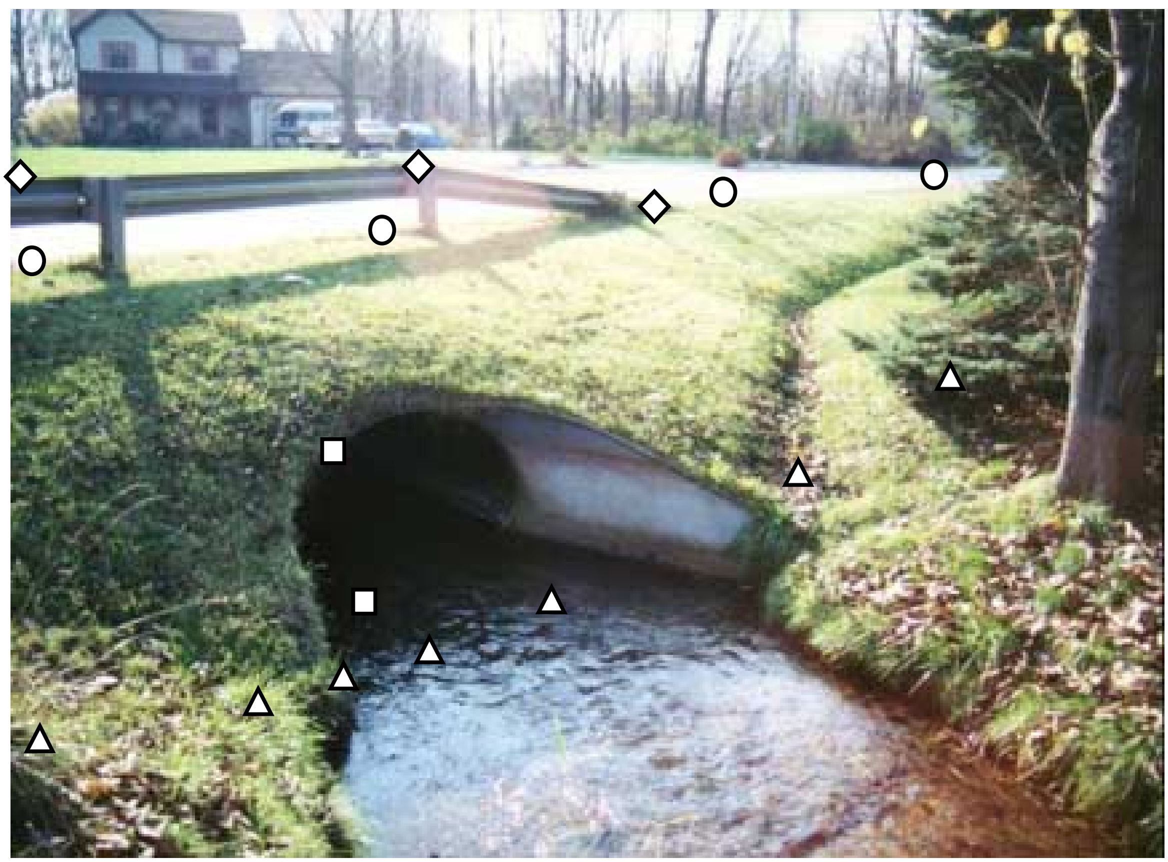
Legend

Symbol	**Description**
△	**Valley cross-section data point**
□	**Bridge opening low chord profile data point**
○	**Road profile data point**
◇	**Guardrail profile data point**
✙	**Pier station/elevation/width data point**









- Horizontal stationing at a bridge or culvert section must be consistent with the downstream and upstream channel-floodplain cross-sections, as well as all areas in between, including the roadway and culvert sections. This consistency enables the reviewer to align the culvert or bridge section with the upstream and downstream channel-floodplain cross-sections. The centerline station of a culvert should be provided and be consistent with the upstream and downstream cross-section stationing.

- The roadway profile should include the lowest weir flow elevations which are usually along the crown of the roadway. However, if there is curb and gutter, the “roadway” profile is often along the top of curb, because the curb top may be higher than the road crown.

- Indicate the length of the culvert or distance between bridge faces along with the width of the roadway.

- Note whether the bridge/culvert crossing is skewed. If it is, the surveyor should provide an estimate of the skew angle of both the roadway and the piers.

- If railing is present at the bridge or culvert, the surveyor should note the type of railing (e.g., solid concrete hand railing). In addition, the profile along the top of the rail should be provided and tied to the same horizontal control as used for roadway.

- If wingwalls or a headwall are present, the material and configuration should be noted.

5.5.2 *Information Particular to Bridge Sections*

- The low chord or low steel profile should be provided using the same horizontal and vertical control as the roadway.

- Provide pier width, shape, and stationing. In cases where the pier width changes as a function of elevation, provide sufficient additional data points needed to define pier shape.

- Abutments should be surveyed at bridge sections. In most cases, a constant slope abutment can be defined with two station/elevation pairs; one at the top of the abutment and one at the toe of the abutment.

5.5.3 *Information Particular to Culvert Sections*

- Specify culvert shape (e.g., round, rectangular, pipe-arch, etc.), dimension, and material (e.g., 48-inch corrugated metal pipe or four foot wide by five foot high reinforced concrete box culvert). Also note the configuration such as projecting from fill, flush with headwall, or mitered with embankment.

- Indicate the depth of sediment within the culvert near its upstream and downstream faces.

- Provide invert elevations at the upstream and downstream ends of culverts and indicate culvert length.

CHAPTER 6

RESEARCHING AND EVALUATING EXISTING MODELS

6.1 Purpose

When planning to use computer modeling as the basis for a hydrologic-hydraulic assessment, prudence suggests searching for existing models. Perhaps computer model input, output and documentation already exist and can be used as is, or modified as necessary, rather than incurring the time and expense needed to develop an entirely new model. Existing models may have been developed for different reasons and the models could be of widely varying quality. Accordingly, the purpose of this chapter is twofold. First, to offer suggestions on how to evaluate the suitability of a model and second, to provide guidance on potential model sources.

6.2 Searching for Existing Models

Many sources can be explored when searching for existing suitable models. Ultimately, the modeler directing the floodplain hydrologic-hydraulic assessment has responsibility for searching for existing models and determining their suitability. The modeler must confirm that an existing model reflects physical conditions at the time of the current study or has been revised to do so. The responsibility for the accuracy and applicability of models obtained from any source is the responsibility of the modeler.

6.3 Evaluating Existing Models

When existing models are discovered, they should be carefully assessed. Factors to consider in determining model suitability include:

- **Model Age:** Models available in the 1970's were executed on mainframe computers. Input and data editing and warning capabilities were primitive compared to what are available today. Accordingly, data errors that show up using current modeling programs may not have been detected when the models were first assembled. Modeling methods have evolved over the years so that what was an acceptable model 20 years ago may not meet current standards.

- **Model Type:** Methodologies and assumptions vary among different modeling programs; an assumption made in one program may not be applicable to another.

- **Model Purpose:** Models are assembled for different reasons. For example, a "rough draft" model may be created for a proposal to perform more detailed modeling or as part of emergency response in times of crisis. While good engineering practice would document these models as being "draft," many times that does not happen.

- **Base Data/Base Mapping Used to Create the Model:** Models often come without documentation describing how the model was developed. Comparing the base data to field data or detailed mapping data may be one way to confirm the quality of the model. Another approach is research the models more thoroughly by examining reports, permit application materials, mapping, and other items that may present clues to the quality of the model.

6.4 Sources of Models

Possible sources of models include:

- **Flood Insurance Study (FIS) Models:** For the majority of streams in Indiana, if BFEs are published in a FIS, they are almost always based on hydraulic modeling. Refer to the FIS to confirm that a model was used. The majority of FIS models are available from FEMA or from the IDNR – Division of Water. Contact the IDNR first because that state agency may have digital copies of the FIS models while FEMA only has hard copies. IDNR files also include backup information for many of the models.

- **Construction in a Floodway Permit Models:** These models have been submitted to the IDNR as supporting justification for the approval of an application for Construction in a Floodway based on IC 14-28-1. However, some projects may have been exempted from modeling requirements and therefore the models may not have been evaluated. Regardless of whether or not the application was approved, these models may be available from the IDNR – Division of Water. While the models are generally available from IDNR in hard copy, some can be provided in digital form.

- **IDNR "Recommendation" or Floodplain Analysis Regulatory Assessment (FARA) Models:** These models have been developed by or submitted to the IDNR – Division of Water to determine floodway limits and BFEs for streams that were not studied in a FIS. In some instances, these are "bare bones" models using minimal information, because no detailed information existed for a stream. Therefore, these models should be used with caution. Potential users are urged to consult with IDNR.

- **Letter of Map Revision Models:** Similar to FIS models, LOMR models are created to support a change to an elevation or floodway published in a FIS. The IDNR – Division of Water and FEMA maintain these models, although, as with FIS models, the IDNR may be the only source for digital copies.

- **IDNR Special Study Models:** The IDNR – Division of Water occasionally will develop a model for a special study, such as a lake control structure or flood control project. Contact the IDNR – Division of Water to determine if such models are available for particular stream reaches.

- **Other Sources of Models:** Some floodplain related projects do not require IDNR approval; however models may exist. In some situations, an engineer may be asked by local permit officials to develop a model for a project site in order to satisfy local planning and zoning ordinances. Accordingly, contact with local government personnel, developers, and engineers may be warranted as a final step in searching for existing models.

The IDNR – Division of Water has many hydrologic and hydraulic models in electronic format that may be downloaded (http://www.in.gov/dnr/water).

CHAPTER 7

GUIDELINES FOR DETERMINING PEAK DISCHARGES

7.1 Purpose

Hydrology is a multidisciplinary subject addressing the occurrence, circulation and distribution of waters of the earth. The discharges for a stream are a function of the stream's watershed characteristics as well as local meteorological conditions. For most purposes in the assessment of the hydraulic properties of a waterway, the hydrologic response of the watershed is reflected in the value of the peak discharge. The purpose of this chapter is to detail the most widely accepted methodologies for estimating peak discharges. These methodologies include the Coordinated Discharge program, discharge determination by the IDNR, and obtaining discharges using a rainfall—runoff model.

7.2 Coordinated Discharges

Many Indiana streams feature coordinated discharges which means that the IDNR, Natural Resource Conservation Service (NRCS), USACE, and USGS have developed and agreed upon discharges for certain streams. Discharge versus drainage area graphs or tables for these streams are available at the IDNR website (http://www.in.gov/dnr/water). Directions for using and determining discharges using these graphs are also included on this website.

For IDNR approval purposes, if a coordinated discharge is available for a modeled study reach, then that is the only discharge acceptable to the Department. The IDNR will not determine a discharge for an applicant that is on a coordinated stream, but will review a determination performed independently. Refer to the website for directions on determining discharges, along with directions for submitting a determination for review.

IDNR practice requires that the discharges used in a FIS be coordinated. Therefore, FIS models obtained from IDNR should, with limited exceptions, be based on coordinated discharges.

While it is possible to challenge and modify a coordinated discharge, the IDNR discourages modification unless discharges are analyzed, and modified as needed, for an entire watershed. Changes to coordinated discharges must be supported by detailed hydrologic modeling and/or gage analysis. In addition, coordinated discharges that are in a published FIS must be changed for the entire stream reach through a LOMR. The requester is responsible for performing all hydrologic and hydraulic modeling and redelineation of all floodplain and floodway boundaries, including obtaining necessary approvals from the IDNR and FEMA.

Coordination of the modeling efforts with IDNR personnel in the early stages of such an effort is essential.

7.3 Discharges Determined by IDNR

For streams where coordinated discharges are not available, the IDNR will estimate the 100-year peak discharge upon request. Because the IDNR usually has jurisdiction over only the 100-year peak discharge, peak discharges for other frequencies will not be determined by the Department. Address requests to the IDNR's Technical Services Center and include:

- stream name as it appears on the USGS 7 ½ minute quadrangle,
- location of point(s) where discharge is needed (e.g., County, road intersections, Section, Township and Range), and
- a copy of the USGS quadrangle with specific point(s) marked.

The IDNR determines discharges based on one or more of the following methods:

- NRCS Unit Hydrograph method
- USGS Regression equations (Glatfelter, 1984)
- IDNR, Division of Water Regression equations
- Previous determinations on the same stream
- Determinations for similar nearby streams
- Discharges for similar gauged streams
- Discharges for similar coordinated streams
- Other methods that may be available

IDNR's 100-year peak discharge determination is not made based on one particular method, but rather on engineering judgment used to evaluate the merits of each method and estimate the appropriate discharge to use.

7.4 Discharges Determined by Others and Submitted to the IDNR for Approval

Instead of having the IDNR determine discharges, other knowledgeable individuals or organizations can develop discharges and submit them to the IDNR for review. The decision to exercise this option should be followed by a meeting, early in the hydrologic analysis process, with IDNR's Engineering Service Center staff.

Factors to consider in determining discharges for submittal to IDNR are described below.

For rainfall depths and distributions within a hydrologic model, IDNR will only accept:

- U.S. Weather Bureau Technical Paper 40 rainfall depths and either NRCS Type B (6 hour) or Type II (24 hour) distributions, or

- Illinois State Water Survey Bulletin 71 (Huff-Angel) depths and distributions

The prescribed rainfall information is available on the IDNR website (http://www.in.gov/dnr/water). Mixing and matching depths and distributions is not acceptable, nor are other sources of depths or distributions.

The hydrologic analysis can be based on a statistical analysis of gage data following the guidelines set forth in Bulletin 17B by the Interagency Advisory Committee on Water Data. The hydrologic analysis report must explain the source of all data, which are typically peak discharges observed and recorded regularly over a period of time by a government agency or private firm. Historical events, which refer to isolated peak discharges observed outside the systematic period, should be documented. The report must also include any adjustments made to the statistical data/record, such as the use of data from a second gaging station to extend a short record or adding data for missing flood years.

For many applications, an acceptable method of determining the appropriate duration is to run a model with a series of different durations and select the "critical" duration, that is, the duration that results in the highest peak discharge.

The IDNR will not accept a discharge that is based on the effect of detention basins that are not approved as flood control projects under IC 14-28-1-29 and that are not operated and maintained by a government entity in perpetuity. This includes the majority of subdivision detention basins. If a project is approved as a flood control structure under IC 14-28-1-29, then the effect of the storage caused by the structure can be included in the hydrologic model.

Reduced discharge resulting from a restrictive stream crossing, such as a railroad fill, may not be used downstream of the structure unless the structure is expected to remain in place for the foreseeable future, and the peak discharge is reduced by 15% or more. When that occurs, the reduced (routed) discharge must be agreed upon and coordinated through the IDNR according to the May 1976 procedure for Coordinated Discharges in order to be accepted. The referenced agreement is done on a case-by-case basis. All routed discharges should be reviewed by the IDNR and approved through the coordination procedure before they are used in a FIS or any other study requiring IDNR approval.

In Indiana, watershed hydrologic response varies greatly depending on location. For example, runoff from a watershed in northern Indiana's "lake country" is dramatically different than a watershed in the rolling hills of the southeastern part of the state. These response differences impact assessment of watershed hydrology in many different ways. For example, when using the NRCS unit hydrograph method, the default unit hydrograph shape is typically not adjusted for the type of terrain or for storage in a watershed. Therefore, the engineer must fully understand the limitations of the methodology used for determining a discharge and the implications for properly applying it to the watershed and its location.

In the science of hydrology there are uncertainties and limitations for any method chosen for the estimation of peak discharges and runoff volumes for a watershed. Evaluation of the rainfall-runoff characteristics of a watershed, especially for rare frequency storms, is extremely complex with many interrelated variables, and existing data are typically too sparse and limited to provide the resulting degree of accuracy involved in many other engineering disciplines. When IDNR determines discharges, many different methods are used to estimate peak discharges and runoff volumes. Consequently, experience and engineering judgment are necessary aspects of making a final determination. Good engineering practice rarely includes one method to obtain a "final answer" for a discharge. Instead, challenge the results by applying other methods, running sensitivity analyses, and/or evaluating other similar watersheds where more information may be available.

Many engineers use a hydrologic modeling program, such as HEC-1, HEC-HMS, or Technical Release 20 (TR-20) to determine discharges for a watershed. While these programs can be very complex and require detailed input data, the results only represent a "well worked out opinion," rather than an absolute answer. The results from these widely used models should be carefully evaluated to ascertain if assumptions inherent in the models adequately reflect the particular system being modeled.

7.5 Historic Flood Profiles and Discharges

After floods of record occur on major Indiana streams and rivers, IDNR has occasionally developed historic flood profiles for these events. Development of historic flood profiles requires a comprehensive effort by trained personnel to determine and establish peak flood elevations along a stream or river by close study of debris limits, flood damage, photographs, local observations, and other sources of information. Obviously, the quality of the historic flood elevation data is dependent upon how soon after the flood event that the field work occurs. Once reliable flood elevations along a reach of stream or river are determined and marked, survey crews then establish benchmarks and tie the located flood elevations into accepted horizontal and vertical datums.

Historic flood profiles provide a valuable tool in development of reasonable 100-year flood profiles for reaches of major streams and rivers. The modeler compares and calibrates a developed flood model profile against an actual flood profile.

Estimating peak discharges for historic flood events on non-gaged streams or rivers typically poses a formidable task and may require extensive hydrologic study and modeling of rainfall-runoff conditions for a specific rainfall event over the contributing watershed area. In the event that control sections such as bridges, culverts, or weirs are located along a stream or river, and reliable high water information has been established both upstream and downstream, it may be possible to estimate the peak discharge for a historic flood event at particular control section locations by performing channel ratings or backwater calculations.

Peak discharge information for a historic flood event should always include analysis of available stream gage information, both in the vicinity and upstream and/or downstream of the study reach, if information is available for the historic flood event. IDNR staff should be consulted when determining peak discharges for historic flood events.

CHAPTER 8

GUIDELINES FOR HYDRAULIC MODELING USING HEC-RAS

8.1 Purpose

The USACE Hydrologic Engineering Center (HEC) has long been recognized as one of the most respected centers for hydraulic modeling software in the water resources community. In the mid 1960's, the HEC began development of models that soon became the water surface profile program HEC-2. For nearly 30 years, HEC-2 was probably the most widely used and accepted program worldwide for determination of water surface elevations. In 1993, the HEC introduced HEC-RAS (River Analysis System), the first version of their Windows based software for water surface profile calculation. The current version of HEC-RAS can be obtained from HEC's website (http://www.hec.usace.army.mil/).

The IDNR encourages the use of HEC-RAS for regulatory and floodplain management purposes within Indiana. While models developed with other software packages are acceptable, this chapter is written from the point of view of developing a HEC-RAS model acceptable to IDNR. The purpose of this chapter is to offer suggestions for more effectively creating and using a HEC-RAS model. Many of the concepts presented here are applicable to many other software packages. Additional issues regarding other modeling packages are discussed in Chapter 9 of these guidelines.

The HEC-RAS model uses the step-backwater method for calculation of water surface profiles. The HEC-RAS manual, along with many basic hydraulic engineering texts, describes this computational methodology. The modeler should have a good working knowledge of methodologies the program uses in the calculation of the water surface profiles. Problems often seen in modeling results could easily be avoided if common hydraulic principles were understood and applied by model developers.

8.2 Program Defaults

The cross-section conveyance default method within HEC-RAS should be used unless the goal of a model is to match a previous HEC-2 model. Refer to Chapter 9 for a more detailed discussion of this topic.

HEC-RAS allows the user to choose from a number of different methods for calculating the friction slope between cross-sections and also enables the program to choose the friction slope equation based on given criteria. The default equation in HEC-RAS, which is the Average Conveyance Equation, should be used.

8.3 Discharges

Options for obtaining discharges are described in Chapter 7. The 100-year peak discharge is used for regulatory purposes in Indiana.

8.4 Starting Water Surface Elevations

In the development of a hydraulic model using the step-backwater method, a boundary condition is required for starting water surface profile calculations. If the flow condition being analyzed is subcritical, the starting water surface elevation at the downstream study reach must be determined using an appropriate method. The 100-year flood for most Indiana streams and rivers typically occurs within the subcritical flow regime. However, the modeler should carefully review flow conditions to determine if supercritical flow occurs in any portion of the study reach. In the event that supercritical flow occurs, application of supercritical or mixed flow (subcritical and supercritical) regime calculations schemes should be discussed with IDNR staff prior to development of a flood model for that reach of stream.

If the flow regime of the entire study reach is determined to be within the subcritical flow regime, the appropriate method as defined by the following Conditions A, B, C, and D should be applied to determine the starting water surface elevation for the flood model:

A. If the study reach of a stream does not include a confluence with a large receiving stream or river and the purpose of the model is to calculate either the flood profile or floodway, determine the starting elevation based on the following priority:

   1. If an accepted flood study has previously been developed downstream, use the ending 100-year flood elevation of the downstream study as the starting elevation. For this to be applicable, the downstream study must abut the downstream end of the proposed study reach, there must be no separation.

   2. If historic flood profiles are available, use the average slope of the historic profile which most closely approximates a 100-year flood profile at the start of the proposed study reach, as defined by the equation in Section 3.5.1, and apply the slope-area method to determine the starting water surface elevation.

   3. Use the average thalweg slope, from best available mapping, at the start of the proposed study reach, as defined by the Equation in Section 3.5.1, and apply the slope-area method to determine the starting water surface elevation.

B. If the study reach of a stream or river is immediately upstream of a confluence with a larger receiving stream or river and the purpose of the model is to calculate the flood profile, determine whether the peak flow conditions of the tributary and the larger receiving stream can be assumed to be coincident. The assumption of coincident peaks may be appropriate if the ratio of the drainage areas at the confluence lies between 0.6 and 1.4, the times of peak flows are reasonably similar for the two combining watersheds, and the likelihood of both watersheds being covered by the storm being modeled is high. Based on whether the assumption of coincident peaks is appropriate, determine the starting elevation as follows:

   1. If the peak flow conditions of the tributary and the larger receiving stream or river can be assumed to be coincident, use the larger receiving stream's computed/published water surface elevation for the flood event being analyzed as the starting elevation for the tributary profile computations.

   2. If the peak flow conditions of the tributary and the larger receiving stream cannot be assumed to be coincident, use the average thalweg slope and slope-area method to start the flood profile near the mouth of the tributary. In this case, the controlling water surface profile for the tributary is plotted as the water surface elevation that has been computed/published for the larger receiving stream, extended horizontally back up the tributary until it meets the computed tributary flood profile.

C. If the study reach of a stream is immediately upstream of a confluence with a larger receiving stream or river and the purpose of the model is to calculate the floodway, use the average thalweg slope, just upstream of the confluence and from best available mapping, and apply the slope-area method to determine the starting water surface elevation of the floodway profile run near the mouth of the tributary.

D. If the study reach of a stream or river is upstream of a flood control reservoir and the purpose of the model is to calculate the flood profile or floodway, use the computed peak flood stage of the reservoir for the flood event being modeled as the starting elevation. For the floodway run, assume that the floodway is as wide as the 100-year floodplain at each cross-section that falls within the 100-year level of the reservoir.

8.5 Manning's Roughness Coefficients

Values of Manning's roughness coefficients ("n") applied in all new flood models require supporting documentation. Also, any modification of "n" values included in published or accepted flood models requires supporting documentation. Many hydraulic engineering texts include tables of “n” values and, in some cases, photographs showing representative values. Many of the sources listed in the bibliography include discussions of applying “n” values. These values are typically representative for streams and rivers in Indiana.

Some factors to consider in selecting roughness coefficients are:

- When choosing “n” values for the base condition model, select values that most likely existed at the time the cross-section data that are being used were obtained. If any new construction existed at the time, use “n” values assuming an aged condition for that portion.

- When choosing “n” values for calibration of a model, use values representative of the conditions existing at the time of the flood being used for calibration.

- When modeling a new project, choose “n” values appropriate for the aged condition of the project.

8.6 Flood Model Calibration

Calibration of a flood model is a tool or procedure to assess “n” values for a flood model. Being able to closely replicate observed flood elevations with a flood model does lend credibility to the model. If available and applicable, use high water marks and discharges provided by the IDNR. Consider other sources of information such as USGS published discharges and USACE high water marks. If available, use stream gage information to the extent that it is applicable.

Consider the quality of the high water marks or gage data when trying to match model results to observations. Tie into any upstream study that has been approved unless errors are discovered in the upstream study’s elevations. If conditions have changed significantly since the time of the historic flood for which high water marks exist, use the high water marks as a guide instead of for direct calibration. Use cross-section data appropriate for the conditions at the time of the flood being calibrated. A model is considered calibrated if it matches good quality, applicable high water marks within six (6) inches.

8.7 Cross-Sections

Cross-section location and orientation guidance is provided in Chapter 5.
The user should verify that the transition top width between any two sections can reasonably occur in the distance between the sections. The user should also verify that changes in distribution of flow between cross-sections is reasonable. As an example, cross-sections that are spaced very close should show similar flow rates in each overbank and the channel. In the event that the flow rates are not similar, the cross-section geometry or parameters may not be appropriate.

Lengths between cross-sections should be measured in each overbank along the anticipated path of the center of mass of the overbank flow. Channel reach lengths are typically measured along the thalweg.

8.8 Ineffective Flow Areas and Blocked Obstructions

Ineffective flow areas and blocked obstructions are often used to represent or approximate the resulting effects of structures or constrictions in a flood model. Ineffective flow represents areas where very low velocity areas are present (i.e., areas having a combination of flow velocities less than 0.5 feet per second and depths less than three feet). Using the ineffective flow area option does not add wetted perimeter to the cross-section.

Blocked obstructions can be used where the cross-section geometry does not include the obstruction. The blocked obstruction option does add wetted perimeter and should be used appropriately.

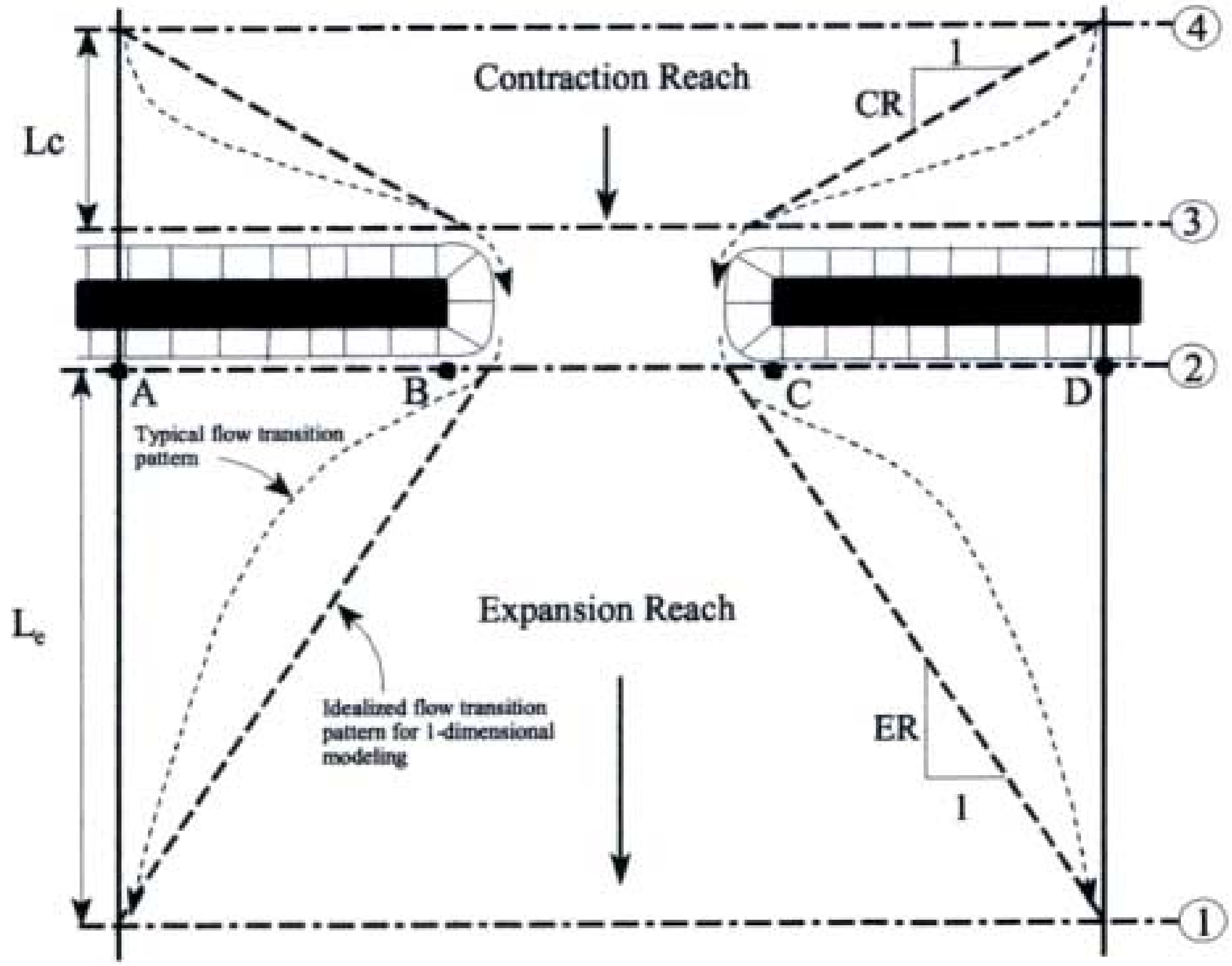
8.9 Bridges

Suggestions for obtaining bridge data are presented in Chapter 5. Presented here are ideas on how to effectively use the bridge data in HEC-RAS.

Figure 8-1 shows the four cross-sections typically needed in the vicinity of a bridge. Cross-section 1 is downstream of the expansion effect of flow coming out of the bridge and its location is usually based on a 2:1 expansion ratio (ER=2) downstream from the bridge.

Cross-sections 2 and 3 should be located at the toe of the bridge fill, respectively, on the downstream and upstream side of the bridge face. However, if there are roadside ditches along the bridge fill, the cross-sections should not include the ditch. Because of the bridge constriction, these cross-sections will not be fully effective across their entire length. Typically, ineffective flow limits are set at these sections to adjust for the contraction and expansion of flow at the bridge. In most cases, the effective flow is slightly wider than the bridge opening at these sections and, therefore, the horizontal placement of the ineffective flow stations should be wider than the bridge opening, based on the expansion and contraction limits at the bridge. Because these ineffective flow limits are representing a water to water interface, under no circumstances should cross-sections 2 or 3 include the fill for the bridge. Also, be aware of the upstream and downstream embankment side slopes on the Bridge Deck/Roadway data editor.

Figure 8-1. Four cross-sections are typically needed in the vicinity of a bridge to adequately represent the bridge in HEC-RAS.



The elevations specified for the ineffective flow limits should correspond to the elevations where flow passes over the crossing approaches. For cross-section 2, the left and right overbank ineffective limiting elevations should initially be set between the maximum elevation of the low chord and the minimum approach roadway elevation on each side of the bridge opening. For cross-section 3, the left and right overbank ineffective limiting elevations should be initially set at the minimum approach roadway elevation on each side of the bridge opening.

After each program run, the bridge calculations output should be reviewed to be sure the flow calculations (e.g. pressure/weir, low flow) are appropriate for the computed water surface elevations and that the ineffective limiting elevations are appropriate.

Cross-section 4 is upstream of the contraction effect of the bridge and is usually set based on a 1:1 contraction ratio (CR=1). On some occasions, conditions dictate that cross-sections either be taken or interpolated within either the contraction or the expansion reach. This is acceptable, provided care is taken so that appropriate ineffective flow limits are included for any interior cross-sections.

Typically, contraction and expansion coefficients in and around a bridge are increased from a standard of 0.1 and 0.3 to values of 0.3 and 0.5. These coefficients should be increased at cross-section 2 (modeling the losses between 1 and 2) and changed back to normal values after cross-section 4. In some instances different values for these coefficients may be appropriate. However, confer with the IDNR in advance of using different coefficients.

Piers and abutments should be represented in the HEC-RAS model. Refer to Chapter 5 for discussion of pier and abutment data.

Energy, momentum, Yarnell, and WSPRO are the four low flow methods within HEC-RAS. Typically the energy and momentum methods are both run and the highest energy answer is used. The Yarnell method, a holdover from HEC-2, is no longer acceptable for modeling purposes. Using the WSPRO method is acceptable but note that additional data are needed for the proper application of this method. Refer to the HEC-RAS or WSPRO manuals for details.

For high flow methods, the two options are the pressure and weir method and the energy (standard step) method. The pressure and weir method should be used where weir flow over the road could occur, typically with one to five feet of flow over the road with relatively narrow floodplains. The weir length used in the model must be consistent with the flow width upstream and downstream of the bridge. The energy method should be used in cases where friction losses will dominate, including very wide floodplains, very shallow or very deep flow over the bridge and perched bridges. Verify that if pressure flow is calculated for a bridge, the resulting elevation is such that pressure flow can really occur.

HEC-RAS has the option to use the Multiple Bridge opening method, which can mix and match the high flow methods with culvert methods and "normal cross-section" methods to more accurately model a bridge. See the HEC-RAS manual for more information. Other types of hydraulic structures can be modeled using HEC-RAS, including weirs, gates, and spillways. Refer to the HEC-RAS manual for the proper application of the program for these cases.

8.10 Culverts

In HEC-RAS, the techniques for setting up a culvert model are essentially the same as setting up a bridge model. Refer to the HEC-RAS manual for typical coefficients used for different culvert losses. Carefully examine model results for the reasonableness of the computation scheme, that is, inlet or outlet control.

8.11 Critical Depths

HEC-RAS will default to a critical depth solution in two common instances:

- The program cannot solve the equations in a specified number of trials (usually 20)

- The normal depth solution indicates that the flow regime has changed from subcritical to supercritical flow.

The first of these instances is usually indicative of a deficiency with the input data. Engineering judgment is needed to apply corrective measures in these instances. Variations in top width should be checked and abrupt changes should be smoothed by using ineffective flow areas. Abrupt changes in area should also be reduced by the addition of transition sections. Intermediate or interpolated cross-sections could also be added. While the HEC-RAS interpolation routine is useful for this, the HEC-2 interpolation routine is flawed and should not be used. In some cases, more field data may be necessary to alleviate the problems in the model.

If the program is defaulting to critical depth because of an indicated change in the flow regime, the model should be examined carefully to be sure that critical depth would be a reasonable solution. One key that supercritical flow may be a reasonable solution is when a series of consecutive cross-sections default to critical depth. In many cases, deficiencies that prevent solving the equation also cause an apparent switch of the flow regime. HEC-RAS has the ability to model a mixed flow regime, and indicate the location of hydraulic jumps, if present. Instances of supercritical flow are rare in Indiana. Therefore, a model must be carefully evaluated before supercritical or mixed flow can be accepted. Discuss these cases with the IDNR before the submission of models for review.

8.12 Floodways

A floodway is defined by encroaching on each cross-section in succession, reducing equal conveyance on each overbank, so as not to exceed the maximum allowable surcharge. In Indiana, the maximum allowable surcharge is 0.14 feet. Steps that should be followed in the development of the floodway are:

- Calculate the floodway based on the 100-year peak discharge.

- Use method 4 (the equal conveyance method) within HEC-RAS, for the preliminary determination, setting a surcharge limit of 0.1 (or 0.14) feet, to get a computer generated floodway. HEC-RAS method 4 will automatically set the starting elevation for the floodway profile 0.1 (or 0.14) feet higher than the base run water surface elevation.

- Retain bridges in the model for floodway computations.

- Plot the computer generated encroachment stations on the project mapping. Plot the floodplain limits as a guide for critiquing the preliminary floodway.

- After plotting the computer generated encroachment stations, choose revised encroachment stations to be input to the model and tested for allowable surcharges based on:

  - Smooth floodway boundaries (avoid hour glass effect)

  - Maximum surcharges of less than 0.15 feet when comparing the "base model" elevation and the "base model with floodway" elevation

  - Choose easily definable and locatable boundaries where possible

- If the model required the establishment of ineffective flow limits at a bridge, set the base model encroachment stations at the limits of the ineffective flow. The floodway to be plotted on mapping, however, should not be based on these stations but on the encroachment stations at the closest stations that are not artificially narrowed. In other words, the floodway should not be "necked down" at a bridge, but should be delineated using the cross-sections just outside the contraction or expansion zones (cross-sections 1 and 4 as defined in Figure 8-1)

- Apply encroachments for determining a floodway at any effective flow cross-section if effective flow at that section is defined as a "natural" ineffective flow area and not due to a bridge.

- When road overflow occurs, adjust the initially calculated encroachment stations to be aligned with properly adjusted upstream and downstream delineations.

- Do not encroach, for floodway purposes, in the channel

- If used, interpolated cross-sections should be identified as such and then used as a guide for, but not exact stationing for, the floodway boundary.

- When delineating the floodway boundary between cross-sections in the model, the floodway should:

    - not be narrower at any spot between sections than at the section on either end

    - follow the general shape of the valley

    - be contained within the floodplain

- Where levees are approved and credited with 100-year protection, draw the floodway limit on the landward toe of the mainline and tributary levees.

- Base a floodway on a channel improvement project as long as that improvement is maintained and operated by a government entity or is an IDNR approved flood control project.

- Decisions made regarding the floodway boundary based on criteria other than that described in the preceding should be annotated in the floodway model after discussion with the IDNR.

- In the past, "eye-balled" floodways (floodways drawn by following the floodplain but cutting off odd shaped portions to create smooth looking delineations) were allowed. These should be avoided unless there is no alternative. Prior approval should be obtained through the IDNR. If there is no alternative and an "eye-balled" floodway is used, the reason must be documented.

- Because cross-sections should span the entire floodplain as previously described, a floodway may not be calculated by a model that uses truncated cross-sections.

- The floodway upstream of a restrictive structure (e.g., some railroad crossings) or approved flood control structure which temporarily stores water should be the entire area used for storage of the 100-year flood.

- When the 100-year flood discharge is confined to a long culvert approved under the Flood Control Act (or existing prior to January 1, 1973) and there is no overland flow, the floodway is delineated overland as the vertical extension of the width of the culvert.

- If a culvert approved under the Flood Control Act features overland flow during the 100-year flood, the vertical extension of the width of the culvert plus the overland flow area is the floodway.

- If the culvert was not approved or grandfathered under the Flood Control Act, the floodway should be both the pre-construction floodway plus the post-construction floodway.

- The floodway option in HEC-RAS often calculates wide floodways with velocities less than 0.5 feet per second and shallow (less than three feet) depths if there is a wide floodplain and low velocities in the overbank. Because of the low velocities and depths, it is often hard to justify calling portions of the area floodway. (This applies to significant reaches where this occurs, not just a couple of cross-sections here and there.) When this situation occurs, it must be discussed with IDNR staff prior to delineation.

- Naturally occurring areas (not elevated as a result of construction or land development) which are above the BFE but which lie planimetrically within the final calculated encroachment stations may be shown to be out of the floodway if the "island" is included in the model.

- The final floodway stations for each cross-section should be specifically entered into the model, using method 1. This will allow future users of the model to know explicitly where floodway stations were chosen at the time of the delineation of the floodway.

8.13 Check RAS

FEMA developed Check-RAS, a program that performs a basic level check of a HEC-RAS model for various errors and reasonableness. The program offers these five checking routines:

- NT (Manning's roughness coefficients and transition loss coefficients)

- XS (cross-sections)

- Structures (bridges and culverts)

- Floodways

- Profiles (if more than one is computed)

Proper completion of the Hydraulic Modeling Checklist requires the modeler to run and submit all applicable reports using this program. All errors or warnings shown as comments in the Check-RAS reports should be reviewed by the modeler and either fixed or explained in a written report, to be included with the submitted model, why the error or warning could not be fixed. Reports generated by Check-RAS should be evaluated using engineering judgment, since some messages can be explained by examination of the model. However, the reports are a extremely useful guide for correcting coding errors and determining values for bridge coefficients.

CHAPTER 9

GUIDELINES FOR ALTERNATIVE HYDRAULIC MODELS

9.1 Purpose

As explained in Chapter 8, the IDNR prefers the use of HEC-RAS for hydraulic modeling. However, circumstances occasionally arise where another hydraulic model program may be used in place of HEC-RAS. For example, a model may already exist in another format or study reach conditions may dictate the use of an unsteady flow model. The purpose of this chapter is to discuss some of the issues that should be considered when using other hydraulic models.

9.2 HEC-2

HEC-2 is the predecessor of HEC-RAS. In the process of converting HEC-2 to Windows, a couple of calculation methods were changed, which must be considered when converting models:

- The main computational change from HEC-2 to HEC-RAS is the method for computing conveyance at each cross-section. HEC-2 computed conveyance at each coordinate point along the cross-section and summed these partial conveyances across the section. The default in HEC-RAS is to compute conveyance zone at breaks in Manning's "n" value across the section and then take the sum of all partial conveyances. While the differences between the two methods for the calculation of water surface profiles are not usually large, they will not match exactly.

  HEC-RAS has the option to compute the conveyance either way, but the "breaks at Manning's "n" values only" is the default. The practice of the IDNR is to use the default within HEC-RAS for new models, but if the purpose of the model is to replicate a previous HEC-2 model, then it is acceptable to use the HEC-2 style of conveyance calculations.

- The other major difference between HEC-2 and HEC-RAS is the method for computing the losses at bridges and culverts. Often the conversion of the data for the "Special Bridge" method in HEC-2 will not be sufficient in HEC-RAS. Engineering judgment is needed for each bridge to determine if the converted bridge modeling is accurate.

- An item of concern in bridge modeling is the difference in representing the road fill at bridge sections. In HEC-2, the coordinate points for the base cross-section and coordinate points for the bridge fill had to match exactly for fill outside of the bridge opening. However, many times care was not taken in making sure that this was done, and the result was that “cracks” would occur between the road fill and the base cross-section. As a result, a large amount of wetted perimeter would be incorrectly added to a bridge section, without adding a comparable amount of area. HEC-RAS solves this problem by “clipping” the road fill using the base cross-section. Therefore, the “low chord” information should be deleted from a converted HEC-2 model outside of the actual bridge opening.

9.3 Revisions to HEC-2 Models Using HEC-RAS

FEMA recently released guidance (dated April 30, 2001) regarding the conversion of HEC-2 models to HEC-RAS for Map Revisions. FEMA policy, which is acceptable for IDNR purposes, is:

- The complete effective HEC-2 model should be converted to a HEC-RAS model using the conversion routine within HEC-RAS.

- Elevation differences between the two models should be fully explained. Usually, differences are caused by the conveyance calculations, the bridge calculations, critical depth problems or differences in floodway calculations.

- The HEC-RAS model must tie in with the effective profile within 0.5 feet at the upstream and downstream ends of the revised reach.

- From there, revisions to the model can be done within HEC-RAS.

In other words, if the goal is to revise a portion of a HEC-2 model, it is not necessary to convert and correct the entire model (as previously required). Instead, convert the entire model, document the problems in conversion, correct the portion of the model of interest (at the point where it can be tied into the existing profile), and use the HEC-RAS model for further revisions.

9.4 Other One Dimensional, Steady State Models

9.4.1 *WSPRO*

WSPRO is the hydraulic model developed by the USGS and the FHWA to compute water surface profiles and losses at bridges. The WSPRO methodology for modeling bridges is somewhat different than HEC-RAS in terms of coefficients and cross-section locations. In a recent revision to HEC-RAS, the WSPRO methodology was incorporated as an option in the bridge loss calculation routines. Use of both the WSPRO model and WSPRO method within HEC-RAS are acceptable, but the differences between the two methodologies should be taken into account during the modeling. WSPRO does not have a floodway calculation routine.

9.4.2 *E431*

E431 is the predecessor of WSPRO, it is no longer supported and is not available for a personal computer. However, a number of FISs were completed using E431 and would need to be converted to HEC-2 or HEC-RAS before they can be revised. Programs are available for performing a limited conversion of a E431 model to HEC-2.

9.4.3 *WSP2*

WSP2 is the water surface profile program developed by the NRCS and it was used for FISs completed by the NRCS. Recently, the NRCS developed WRAS, which will convert WSP2 models to HEC-RAS. Generally not used anymore, WSP2 is acceptable for small changes to models.

9.4.4 *Unsteady State Models*

Hydraulic modeling has traditionally been based on the assumptions of steady state flow and that storage effects are minimal along the stream reach. However, there are some situations in Indiana where both of these assumptions cause problems when evaluating and debugging a model. Examples of these cases are flat streams with wide overbanks that act as storage areas for flood waters; in-channel dams, gates, weirs or control structures; and regional detention facilities. In these instances, among others, it may be desirable to use a more complex unsteady state model to determine regulatory BFEs.

In the past, the computing power required to solve the complex equations made the use of unsteady state flow models prohibitive. With advances in personal computers, today running an unsteady state flow model has become a feasible option. However, these models are very complex and a wide base of knowledge and experience has not yet developed within the engineering community. Therefore, these models should be used with caution and coordination with the IDNR prior to using these models is essential.

One issue that has not been addressed by any agency is the development of floodway criteria for unsteady state flow models. The concepts of floodway definition and delineation outlined in previous chapters cannot be directly applied to unsteady state flow situations. In the development of these models, interpretation of the floodway should be done in a manner consistent with the intent of the floodway surcharge criteria for steady state flow (i.e., equal to or less than 0.14 feet), but drawing a floodway that is “smooth with consistent topwidths” and which has “excessive velocities” may not be possible with the inclusion of storage areas.

9.4.5 *HEC-RAS (Unsteady State Flow Routine)*

One advance in the availability of unsteady state flow models beginning with the release of HEC-RAS 3.0, which includes modules for computing steady and unsteady state flow. These computation routines are borrowed from the model UNET. With the inclusion of these routines in a Windows environment and using the same section editing scheme as previous versions of HEC-RAS, compiling and running an unsteady state model is now easier. Users should recognize that an unsteady state model requires much more review and scrutiny than traditional steady state models.

9.4.6 *UNET*

UNET can be viewed as the unsteady state version of the USACE HEC-2; however, it was developed separately from HEC-2. UNET can be used to model items such as levees (including levee failures), ponds, tunnels, gates, weirs and natural storage areas. Unless an engineer is working with an old model already done in UNET, there is little reason not to use HEC-RAS 3.0 instead.

9.4.7 *ICPR*

ICPR (Interconnected Pond Routing Model) was developed by Streamline Technologies for modeling stormwater ponds in series, with full incorporation of tailwater effects. It also has the ability to model other types of structures, such as bridges and culverts, and to model overbank storage.

ICPR combines the hydrologic and hydraulic analyses within the same model. Discharge hydrographs are generated using alternative rainfall-runoff transformation methods and alternative rainfall distributions. The unsteady flow capabilities of ICPR allow for routing of the actual generated subbasin hydrograph at specified nodes rather than just the peak discharge. A node may represent the confluence of a subbasin with another subbasin, a detention facility, a channel reach (open or pipe), or a diversion location, etc.

CHAPTER 10

PRESENTATION OF MODELING RESULTS

10.1 Purpose

Effective presentation of modeling results facilitates ultimate acceptance of the analysis. A well constructed and documented model is easier to review, both internally and by IDNR, and time invested up front in documentation is often recouped by shorter review times. In addition, a well documented model is easier to use when subsequent modeling efforts on the same stream are initiated. The purpose of this chapter is to provide suggestions on how to effectively present the modeling that supports a floodplain hydrologic-hydraulic assessment.

10.2 Hydraulic Modeling Checklist

The IDNR Hydraulic Modeling Checklist is included as an appendix of these guidelines. The current version can be obtained at the IDNR website. (http://www.in.gov/dnr/water). The checklist is consistent with and reinforces the concepts and suggestions presented in these guidelines.

The checklist will help a requester provide the IDNR with data and information needed to conduct the review process in accordance with the Department's minimum standards of acceptability. Moreover, the checklist introduces questions intended to elicit specific answers to a number of common and important modeling issues. The questions serve a dual purpose:

- suggest a method for checking the viability of the model by looking at the way in which data are presented and by evaluating the quantitative output, and

- obtain answers the reviewer can use to gain greater insight in assessing site conditions and project impacts.

The modeling checklist promotes familiarity, increases understanding, and lessens frustration during the review. Ultimately, the engineer spends less time explaining what he or she did and why, and IDNR personnel spend less time trying to determine the modeler's intent.

10.3 Hydraulic Modeling Documentation

FEMA and IDNR recommend that all the documentation for a model be presented in a notebook form, including a narrative regarding the modeling, the checklists and application forms, model output and results, cross-section and profile plots, tables, photos and any other relevant support materials.

Plans, maps or drawings should be clean, clear and concise, neatly drawn and presented, and have all of the elements suggested in the checklist.

Site photographs provide an excellent way to document the selection of Manning roughness coefficients and bridge and culvert geometry without requiring the internal or external reviewer to go onsite. Refer to Figure 5-2 in these guidelines for example photographs. For advice on photography in support of modeling, refer to the IDNR permit manual which is available on the Department's website (http://www.in.gov/dnr/water).

Another characteristic of a good model is documentation within the model. HEC-RAS provides a place in almost every screen where comments can be made. Use this feature to fully explain modeling assumptions and to clarify modeling data.

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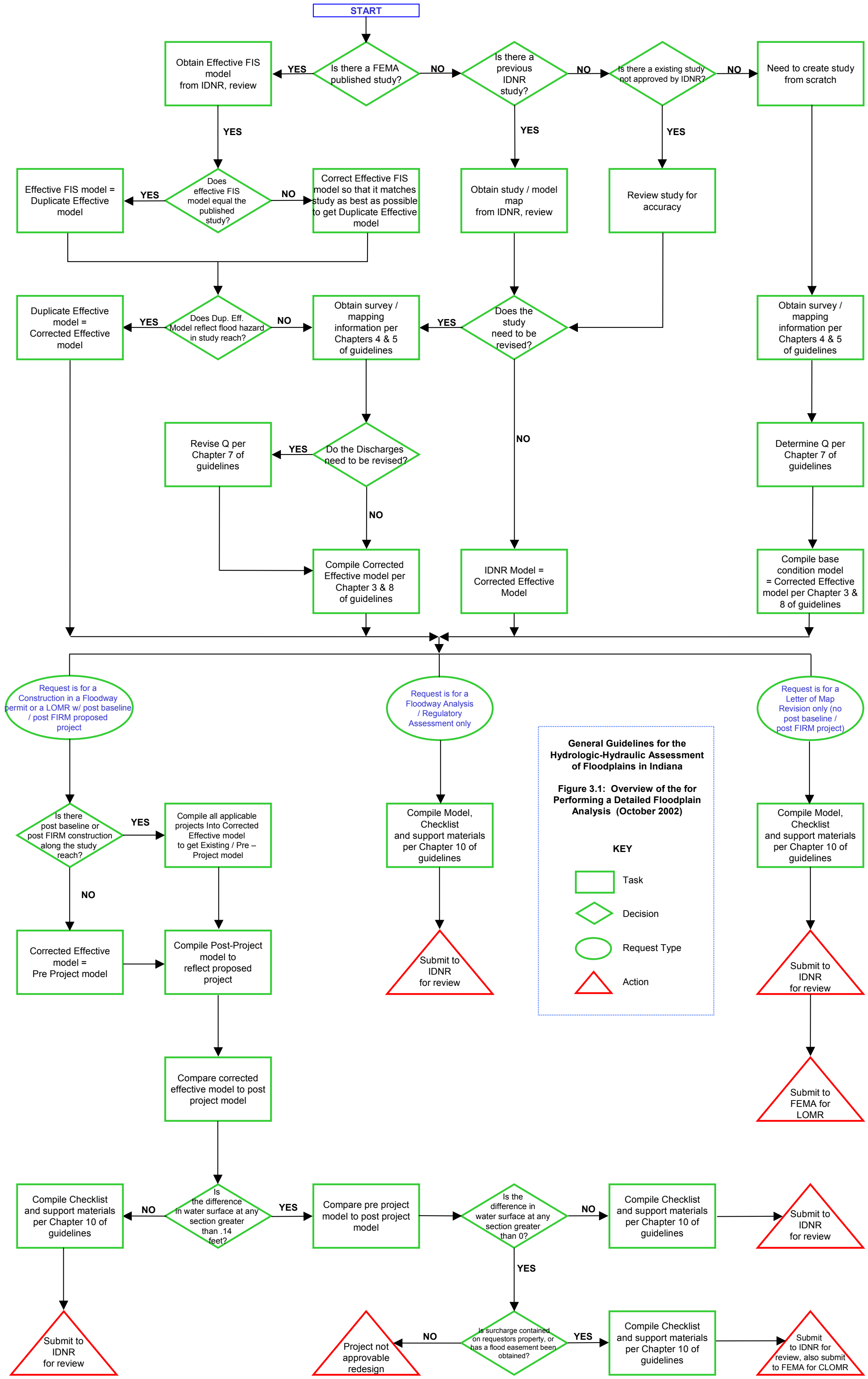
APPENDIX

FLOW CHART:
OVERVIEW FOR PERFORMING
A DETAILED FLOODPLAIN ANALYSIS


START
Is there a FEMA published study?
YES
Obtain Effective FIS model from IDNR, review
NO
Is there a previous IDNR study?
NO
Is there a existing study not approved by IDNR?
NO
Need to create study from scratch
YES
Does effective FIS model equal the published study?
YES
Effective FIS model = Duplicate Effective model
NO
Correct Effective FIS model so that it matches study as best as possible to get Duplicate Effective model
YES
Obtain study / model map from IDNR, review
YES
Review study for accuracy
Does Dup. Eff. Model reflect flood hazard in study reach?
YES
Duplicate Effective model = Corrected Effective model
NO
Obtain survey / mapping information per Chapters 4 & 5 of guidelines
YES
Does the study need to be revised?
Obtain survey / mapping information per Chapters 4 & 5 of guidelines
Do the Discharges need to be revised?
YES
Revise Q per Chapter 7 of guidelines
NO
NO
Determine Q per Chapter 7 of guidelines
Compile Corrected Effective model per Chapter 3 & 8 of guidelines
IDNR Model = Corrected Effective Model
Compile base condition model = Corrected Effective model per Chapter 3 & 8 of guidelines
Request is for a Construction in a Floodway permit or a LOMR w/ post baseline / post FIRM proposed project
Request is for a Floodway Analysis / Regulatory Assessment only
Request is for a Letter of Map Revision only (no post baseline / post FIRM project)
Is there post baseline or post FIRM construction along the study reach?
YES
Compile all applicable projects Into Corrected Effective model to get Existing / Pre – Project model
NO
Corrected Effective model = Pre Project model
Compile Post-Project model to reflect proposed project
Compile Model, Checklist and support materials per Chapter 10 of guidelines
Submit to IDNR for review
Compile Model, Checklist and support materials per Chapter 10 of guidelines
Submit to IDNR for review
Submit to FEMA for LOMR
General Guidelines for the Hydrologic-Hydraulic Assessment of Floodplains in Indiana
Figure 3.1: Overview of the for Performing a Detailed Floodplain Analysis (October 2002)
KEY
Task
Decision
Request Type
Action
Compare corrected effective model to post project model
Is the difference in water surface at any section greater than .14 feet?
NO
Compile Checklist and support materials per Chapter 10 of guidelines
YES
Compare pre project model to post project model
Is the difference in water surface at any section greater than 0?
NO
Compile Checklist and support materials per Chapter 10 of guidelines
Submit to IDNR for review
Submit to IDNR for review
YES
Is surcharge contained on requestors property, or has a flood easement been obtained?
NO
Project not approvable redesign
YES
Compile Checklist and support materials per Chapter 10 of guidelines
Submit to IDNR for review, also submit to FEMA for CLOMR

APPENDIX

HYDRAULIC MODELING CHECKLIST

Division of Water
Indiana Department of Natural Resources
Hydraulic Modeling Checklist

This checklist will assist the staff at the Division of Water in the review of modeling for the definition of the floodway, for evaluation of a Construction in a Floodway permit application, for state concurrence of a Letter of Map Revision or a Flood Insurance Study or any other modeling that is submitted for review. The checklist items are based on the document "General Guidelines for the Hydrologic-Hydraulic Assessment of Floodplains in Indiana." The modeler should be familiar with this document and any discrepancies between the general guidelines and the submitted modeling should be discussed with the Division of Water Engineering Services staff prior to submittal.

This completed checklist must be submitted to the Division of Water along with your models. The Division of Water <u>will not</u> review any modeling submittal that is not accompanied by a completed checklist.

Please keep in mind that these questions were written primarily for the application of HEC-RAS computer models. HEC-RAS is preferred by the Division of Water, however, other modeling programs may be used provided their use has been discussed previously with Division of Water Staff. Should you have any questions, please contact Division of Water staff at (317) 232–4160 or toll free at (877) 928-3755.

1. **General Information**

   a. Preparer Name: ______________________________
   (Name of individual who prepared the submitted modeling)

   b. Preparer Firm: ______________________________

   c. Date: ______________________________

2. **Project Location and Background Information**

   a. Waterbody Name: ______________________________
   ____
   (Use name as shown on USGS 7 ½ minute quadrangle)

   b. Location Description: ______________________________
   ____
   (Example: Along the west bank of Blank Creek beginning at Culvert Avenue and extending upstream (north) approximately 2,000 feet to C.R. 700 North)

   c. Nearest Town/City: ______________

   d. County: ______________

   e. Downstream End of Project Location:

   Section: _____ Township: _____ Range: _____ Quadrangle: __________
   (if the project is in a grant, reserve or donation, check here and give information below) ☐
   ____

Waterbody Name: ______________
Preparer: ____________________
Date: _______________________

Upstream End of Project Location:

Section: _____ Township: _____ Range: _____ Quadrangle: ______________
(if the project is in a grant, reserve or donation, check here and give information below) ☐

____

f. Study Reach Location: Downstream Limit _________ ________ *(unit of distance)*

Upstream Limit _________ ________ *(unit of distance)*

(Limits should be measured in miles from the mouth of the stream or use units of distance consistent with published flood study. The Division of Water has mileage on many streams.)

g. Type of Model

☐ HEC-RAS ☐ HEC-2 ☐ WSPRO ☐ WSP2 ☐ HY-8

Other _________________

h. Published Flood Insurance model *(Name, Study Reach and Date)* ___________________

i. IDNR model *(Name, Study Reach and Date)* ___________________________________

j. Previous FARA / Floodway Permits within study reach *(Application Number and Approval Date)*

1. ____
2. ____
3. ____
4. ____
5. ____

3. Request Information

Please indicate for what purpose the models are submitted for review and approval:

☐ Floodway / Base Flood Elevation Determination (FARA)
☐ Construction in a Floodway Application
☐ Letter of Map Revision (LOMR)
☐ Flood Insurance Study modeling
☐ Other (please describe) ____
____

Waterbody Name: _______________
Preparer: ______________________
Date: _________________________

4. Discharges

The source of the 100-year frequency flood discharges used in a hydraulic model need to be fully documented by completing the questions listed below.

It is strongly suggested that a preparer-determined 100-year discharge be submitted for approval prior to the submittal of hydraulic models. Discharge determinations and hydraulic models are considered to be separate items, each subject to review.

a. What is the source of the discharges used in the submitted model *(Please check one):*

- ☐ Discharges based on a curve published in "Coordinated Discharges of Selected Streams in Indiana"
  (Please attach copy of applicable graph)
- ☐ Discharges based on a determination from the Department of Natural Resources
  (Please attach copy of letter from IDNR)
- ☐ Discharges based on hydrologic analyses submitted with this model
  (Please attach a copy of the IDNR approval letter)
- ☐ Discharges from a Flood Insurance Study
- ☐ Discharges from other modeling *(Indicate source)* ________________________________

b. Table of Discharges used in the model *(Expand table as needed)*

Drainage Area (sq. mi.)	**Discharge (cfs)**	**Cross-Section / Location Where Discharge is Specified**

c. Comments regarding discharge determination:

____
____
____
____
____
____
____
____

Waterbody Name: ______________
Preparer: ____________________
Date: ______________________

5. Starting Elevation / Boundary Conditions

Complete the following section fully to document the starting elevations and boundary conditions for starting the model:

a. Boundary condition used to derive starting elevations: *(Please check one)*

- ☐ Known water surface *(Indicate source):* ______________________________
- ☐ Energy slope estimated from historic flood profile *(Indicate date):* ______________
- ☐ Energy slope estimated from stream thalweg *(Indicate mapping used):* __________
- ☐ Other *(Please Describe):* ______________________________________

b. Description (show any calculations):

____

____

6. Manning's Roughness Coefficients ("n" Values)

Complete the following section fully to document the Manning's roughness coefficients:

a. How were the roughness coefficients estimated? *(Check all that apply)*

- ☐ Flood Insurance Study
- ☐ Other modeling
- ☐ Field inspection
- ☐ Site photos
- ☐ Aerial photography or mapping
- ☐ Calibration
- ☐ Other *(Describe)* ______________________________________

b. What is the range of the roughness coefficients?

Left Overbank	Minimum __________	Maximum __________
Channel	Minimum __________	Maximum __________
Right Overbank	Minimum __________	Maximum __________

c. Are proposed roughness coefficients different from the base roughness coefficients?
☐ Yes ☐ No

Note: In most cases, the Department will not approve modeling based on an "improved" condition. If the "Yes" box is checked, you will need to justify the use of the modified roughness coefficients below. It is strongly suggested that these issues should be discussed with personnel at the Department prior to submittal.

Waterbody Name: _______________
Preparer: ______________________
Date: __________________________

d. Description of “n” values

Please further describe the methods checked above that were used to estimate the roughness coefficients. If they are estimated from photos, please attach copies of the photos, along with an orientation map. If the roughness coefficients are estimated by calibration, please submit supporting documentation.

e. Check-RAS

For HEC-RAS models, please run the “NT” report from Check-RAS and attach it to this checklist. List any comments in the model and justification for not correcting these comments (use additional sheets, if necessary):

Waterbody Name: ______________
Preparer: ____________________
Date: _______________________

7. Cross Sections

The following questions have to do with the cross section information that is the basis of the submitted modeling:

a. What is the source of the cross section information *(check all that apply):*
- ☐ Flood Insurance Study
- ☐ Field survey *(Date)* ____
- ☐ Detailed topographic mapping *(Date)* ____________________________
- ☐ Other modeling *(Indicate source)* ______________________________
- ☐ Other *(please specify)* ______________________________________

  ____

b. Are cross sections stationed increasing from left to right looking downstream?
☐ Yes ☐ No

c. How are sections labeled *(check one)* (Note: The following list is in order of preference)
- ☐ Consistent with FIS / other studies
- ☐ Miles above mouth
- ☐ Feet above other landmark *(Please specify landmark)* _________________
- ☐ Other *(Please specify)* ______________________________________

d. Are sections oriented perpendicular to flow at all portions of the cross section?
☐ Yes ☐ No

e. Are the full cross section extents shown on submitted mapping?
☐ Yes ☐ No

f. Do the cross sections extend fully across the floodplain *(above expected 100-year flood elevations)*?
☐ Yes ☐ No

g. Do the cross sections represent average conditions in the reach at which they are located?
☐ Yes ☐ No

h. Are areas of blocked or ineffective flow indicated on the submitted cross sections?
☐ Yes ☐ No

i. Are cross sections located at places where discharge values change along the stream reach?
☐ Yes ☐ No

Waterbody Name: ______________
Preparer: ____________________
Date: ______________________

j. For any “No” answers above, please provide an explanation:

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k. Are interpolated sections used anywhere in the model (if yes, state reasons for using interpolated sections)

☐ Yes ☐ No

Reason: ____
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l. Check-RAS

For HEC-RAS models, please run the “XS” report from Check-RAS and attach it to this checklist. List any comments in the model and justification for not correcting these comments (use additional sheets, if necessary):

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Waterbody Name: ______________
Preparer: ____________________
Date: ______________________

8. Bridges

The following questions should be answered for each bridge in the model being submitted. Use a separate sheet for each bridge

a. Name of Bridge in model: ____

b. Bridge cross-section locations *(See Section 8.9 of the Guidelines for location of bridge sections):*

Section 1 Cross-section number: __________
Section 2 Cross-section number: __________
Section 3 Cross-section number: __________
Section 4 Cross-section number: __________

c. Is this model submitted in support of a Construction in a Floodway application for the bridge in question?

☐ Yes ☐ No

d. If the answer to c is "yes," then are the same number of sections used in the existing (or pre-project) and proposed (or post-project) model?

☐ Yes ☐ No ☐ N/A

e. Do the cross sections extend across the entire valley to the 100-year frequency flood elevation?

☐ Yes ☐ No

f. Is cross section 1 located at a 2:1 flow expansion ratio downstream of the bridge face?

☐ Yes ☐ No

g. Is cross section 4 located at a 1:1 flow contraction ratio upstream of the bridge face?

☐ Yes ☐ No

h. Have the expansion / contraction coefficients been adjusted to reflect the effects of the bridge?

☐ Yes ☐ No

i. Were effective flow limits set at sections 2 and 3?

☐ Yes ☐ No

j. What is the selected modeling method *(for the 100-year frequency flood only)*

☐ Energy (Low flow)
☐ Momentum (Low flow)
☐ WSPRO (Low flow)
☐ Energy (High flow)
☐ Pressure / Weir flow (High flow)

k. Does approach roadway profile data extend across the full valley cross section?

☐ Yes ☐ No

Waterbody Name: ______________
Preparer: ____________________
Date: ______________________

l. Are bridge piers included in the model?

☐ Yes ☐ No

m. Were HEC-RAS default embankment side slopes applied at all bridge crossings in the model?

☐ Yes ☐ No

n. For all "No" answer above, please provide an explanation:

o. Check-RAS

For HEC-RAS models, please run the "Structure" report from Check-RAS and attach it to this checklist. List any comments in the model and justification for not correcting these comments (use additional sheets, if necessary):

Waterbody Name: _______________
Preparer: ______________________
Date: _________________________

9. Culverts

The following questions should be answered for each culvert in the model being submitted. Use a separate sheet for each culvert:

a. Name of Culvert in model: ____

b. Cross section locations (See Section 8.9 and 8.10 of the Guidelines for the location of culvert sections):

Section 1 Cross section number: ___________
Section 2 Cross section number: ___________
Section 3 Cross section number: ___________
Section 4 Cross section number: ___________

c. Is this model submitted in support of a Construction in a Floodway application for the culvert in question?

☐ Yes ☐ No

d. If the answer to c is "yes," then is the same number of sections used in the existing (or pre-project) and proposed (or post-project) model?

☐ Yes ☐ No ☐ N/A

e. Do the cross sections extend across the entire valley to the 100-year frequency flood elevation?

☐ Yes ☐ No

f. Is cross-section 1 located at a 2:1 flow expansion ratio downstream of the culvert?

☐ Yes ☐ No

g. Is cross-section 4 located at a 1:1 flow contraction ratio upstream of the culvert?

☐ Yes ☐ No

h. Have the expansion / contraction coefficients been adjusted to reflect the effects of the culvert?

☐ Yes ☐ No

i. Were effective flow limits set at sections 2 and 3?

☐ Yes ☐ No

j. Does approach roadway profile data extend across the full valley cross section?

☐ Yes ☐ No

k. Were HEC-RAS default embankment side slopes applied at all culvert crossings in the model?

☐ Yes ☐ No

Waterbody Name: _______________
Preparer: ______________________
Date: _________________________

l. For all "No" answer above, please provide an explanation:

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m. Check-RAS

For HEC-RAS models, please run the "Structure" report from Check-RAS and attach it to this checklist. List any comments in the model and justification for not correcting these comments (use additional sheets, if necessary):

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Waterbody Name: _______________
Preparer: ______________________
Date: _________________________

10. Floodways

Has floodway determination been done in accordance with Section 8.12 of the Guidelines?

☐ Yes ☐ No ☐ N/A

11. Model Output

For all model outputs review the "errors and warnings" and address those comments not already addressed.

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12. Documentation

Submitted documentation *(Check all that apply)*:

- ☐ Narrative regarding modeling
- ☐ Application Forms and/or LOMR Application Forms
- ☐ Pictures of stream reach *(w/ orientation map)*
- ☐ FIS map / profile
- ☐ Previous FARA/Floodway permits in study reach *(Including maps)*
- ☐ Check-RAS output
- ☐ Cross Section plots
- ☐ HEC-RAS "Standard Table 1"
- ☐ HEC-RAS "Encroachment 1" table *(Show where the 0.14' surcharge occurs)*
- ☐ Profile plots
- ☐ Summary of Modeling and Project Evaluation Results *(Mandatory – See Figure 3.1)*
- ☐ Floodplain mapping including:
  - ☐ Stream in question *(Along with other hydrographic features)*
  - ☐ Roads *(With street names)*
  - ☐ Existing features *(Buildings, parking lots, woods, etc)*

Waterbody Name: ______________
Preparer: ____________________
Date: ________________________

- ☐ The full extent of each cross section included in the model, with each cross section clearly labeled *(Include the location of initial and end points as used in the model)*
- ☐ Contour topographic data *(If available)*
- ☐ Property limits *(Approximate property limits are acceptable only if surcharges are 0.14' or less at all cross sections)*
- ☐ North arrow
- ☐ Scale *(Numerical and graphical)*
- ☐ Horizontal and vertical control benchmark used *(See Section 5.4 of the Guidelines for benchmark guidance.)*
- ☐ Horizontal and vertical datums
- ☐ Delineated flood fringe and floodway limits

  (The flood fringe and floodway should be shaded so that it is obvious to the reviewer what areas are flood fringe and floodway, but not shaded so dark that other features are obscured. For multi-colored plans, the Division of Water convention is to shade the flood fringe blue and the floodway yellow. See Section 8.12 of the Guidelines for delineation guidance.)

- ☐ Disk with input data and model output *(Check all that apply)*
  - ☐ Base Condition (FIS, IDNR Regulatory) File name: __________________
  - ☐ Duplicate Effective File name: ____________________
  - ☐ Corrected Effective File name: ____________________
  - ☐ Existing (Pre-project) File name: ____________________
  - ☐ Proposed (Post-project) File name: ____________________

Waterbody Name: ______________
Preparer: ____________________
Date: ______________________

13. Affirmation

By signing this document you are indicating that the submitted models have been developed and reviewed in accordance with accepted Division of Water procedures, that should the Division of Water find inconsistencies between your submitted models and the checklist, you will be notified in writing of the deficiencies and given 90 days to correct these problems; and that if after 90 days these inconsistencies still exist, you will be notified that your model is unacceptable and the Department will take no further action if the request is for a FARA, or issue a denial notice if the request is associated with a permit application.

____
Date:

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Signature

____
Name

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Firm

Division of Water Use Only

Date Received ____________________________ File Number ___________

Reviewer ____________________________ Date reviewed ___________

☐ Approved ☐ Rejected

Section Manager Review ____________________________